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AUGUST, 1921

THE SCIENTIFIC CAREER FOR WOMEN[1]

By DR. SIMON FLEXNER

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MAY 18 of this year witnessed a notable public event. A gathering of several thousand persons, for the most part college women, filling throughout the huge auditorium of Carnegie Hall in New York, assembled to do honor to a woman who had added a great new fact to science, and that audience was only one of the many that have assembled during the past few weeks for the same purpose. Following as it did so closely on the great war and the homage being paid to military and diplomatic leaders of the victorious nations, the occasion stands forth by contrast as signalling a new and precious order in which the triumphs of the intellect, in this instance as embodied in Madame Curie, received a merited recognition and reward. The statement is often heard that the achievements which society most honors, even in times of peace, are not the laborious ones of learning, but rather the more spectacular ones of the military profession; and it is just this perversion of values which now perhaps more than in any previous period is so disheartening. And yet the event just mentioned by no means lends support to this common point of view, but may rather be looked upon as affording a new hope and inspiring a new courage with which to meet the immeasurably important problems of society now pending.

It is perhaps also permissible to find significance in the fact that the recipient of the high honors now being conferred everywhere in this country on the discoverer of radium is a woman. In view of the discovery itself and the impetus given by it to physical, chemical, and even biological research, it may seem idle to ask the question I have so often heard asked whether there exists a scientific career for women. But there are without doubt many people who will insist that one such achievement, great as it is, can not be taken as setting aside for once and all speculation on the subject. They may continue to doubt.

[1] An address given at the commencement exercises of Bryn Mawr College, on June 2, 1921.

None the less one must admit that Madame Curie's example is a great and encouraging one for women.

The scientific career is not under all circumstances one thing. Its opportunities adapt themselves rather to different times and different types of mind. One of Leonardo da Vinci's aphorisms was that truth is always the daughter of her period. We readily distinguish two main kinds of scientific achievement or discovery so called—one of which is the outgrowth or the efflorescence of a line of investigation dealing with things predictable. The result accomplished may be new and important, but having been foreshadowed by the march of scientific events, it lacks essential novelty. For this kind of discovery, knowledge—often deep and precise—and method, but not the highest talent, are demanded. The other partakes of the accidental rather than the incidental; it never comes as a direct, but rather as an unexpected result or side issue to some line of inquiry, as something for which there is no precedent, and hence it may be easily overlooked. Discovery in this field is more certainly the mark of that individuality to which the designation genius has been applied. Perhaps the qualities which distinguish it may be aptly defined under the phrase invented by Pasteur of the "prepared mind," that is, the mind so gifted with imaginative insight and so fortified by accurate training as to be alert to perceive and quick to seize upon the novel and essential, which is turned at once to unexpected uses. It has been well said that "the discovery which has been pointed to by theory is always one of profound interest and importance, but it is usually the close and crown of a long and fruitful period; whereas the discovery which comes as a puzzled surprise usually marks a fresh epoch and opens a new chapter of science." [1]

The two kinds of achievement are discernible in the work of more than one great investigator. Thus Pasteur's laborious and ingenious studies which led first to the overthrow of the doctrine of the spontaneous generation of life, and then by way of the all important demonstration of the biological nature of the processes of fermentation and putrefaction to the secure founding of the germ origin of infectious disease, may be considered as having been previously foreshadowed; while his epochal discoveries in crystallography and in the domain of immunity were as clearly the harvests of the exceptionally brilliant and prepared mind.

The history of science contains not a few instances in which the line of investigation being carried on at a particular juncture by the master exerts a strong, often indelible and permanently directive impression upon a pupil. Thus, for example, the life work of Professor Theodore Richards in this country, which has corrected and re-

1 Lodge, Oliver, Becquerel Memorial Lecture, Journal of the Chemical Society. Transactions 1912, V. 101, II, p. 2005.

established the atomic weights of certain elements and for which he has received the highest honors in science, was begun under his first professor of chemistry. In like manner Pasteur became imbued with his master Delafosse's enthusiasm for crystal structure, considered with reference to the relation of atoms to the rotatory power upon a beam of polarized light. Hence when Pasteur obtained his first position of "preparateur" to the professor of chemistry, he set himself the task of studying crystal forms and by good chance chose the tartrates in which the phenomena he was seeking appear in the simplest form. Had he chosen other crystals, he would have had to search much longer to find the particular appearances so clear in them, but that in the end he would have succeeded may be assumed. What was constantly in Pasteur's mind at this early period was the correlation between a particular crystalline form called hemihedrism and rotatory power. This relation is determined by little faces on one-half of the edges of the crystals, the existence of which had already been noted by two chemists, the one a conscientious observer without inspiration, or as the French say *sans flamme*, and the other preoccupied with a theory which he endeavored to fit to all the facts which his studies revealed. Both thus failed to understand their significance.

Pasteur's discovery, although strictly speaking a discovery in chemistry, later had its percussion through the entire realm of science in a manner so profound that to-day, seventy years after the event, its reverberations have not yet ceased. His biographer has described it as follows:

"Pasteur noticed that the crystals of tartaric acid and the tartrates had little faces on one-half of their edges or similar angles (hemihedrism). When the crystal was placed before a glass the image that appeared could not be superposed; the comparison of the two hands was applicable to it. Pasteur thought that this aspect of the crystal might be an index of what existed within the molecules, a dissymmetry of form corresponding with molecular dissymmetry. Therefore, he reasoned the deviation to the right of the plane of polarization produced by tartrate and the optical neutrality of the paratartrate would be explained by a structural law. The first of these conclusions was confirmed, but when he came to examine the crystals of paratartrate hoping to find none of them with faces, he experienced a keen disappointment. The paratartrate was also hemihedral, but the faces of some of the crystals were inclined to the right, and those of others to the left. It then occurred to Pasteur to take up these crystals one by one and sort them carefully, putting on one side those which turned to the left, and on the other those which turned to the right. He thought that by obtaining their respective solutions in the polarizing apparatus, the two contrary hemihedral forms would give two contrary

deviations; and then by mixing together an equal number of each kind, the resulting solution would be neutral and have no action upon light. With anxious and beating heart he proceeded to the polarizing apparatus and exclaimed 'I have it.' His excitement was such that he could not look at the apparatus again; he rushed out of the laboratory, not unlike Archimedes. In the passage he met a curator and embracing him dragged him out with him into the Luxembourg gardens to explain his discovery. Many confidences had been whispered under the shade of the tall trees of those avenues, but never was there greater or more exuberant joy on a young man's face. He foresaw all the consequences of the discovery.* * * *"[2]

In like manner there can be no doubt that the discovery by Pasteur in 1880 of the artificial immunity to fowl cholera, which opened up to exploitation the wide and varied field of immunity in medicine and which is to-day one of the main achievements of medical science and is holding out still greater promises of progress in the control of disease in the future, came not as a direct incident, but rather as an accidental circumstance to the experiments on infection being pursued.

So it was also with the discovery of spontaneous radioactivity by Becquerel, to which are directly traceable the discovery of radium, and the superlative and successful efforts now being made to solve the age-long problem of the atomic constitution of matter; while Madame Curie's discovery of radium itself was not the result of a momentary inspiration on her part, but rather the consummation of a labor extending over many years, begun under conditions of great hardship and continued through obstacles and discouragements which only the great in spirit surmount.

I shall not tarry on the threshold of the story to repeat to you the details of the preliminary steps in the great career of Madame Curie, during which she did what was virtually the menial service of the Sorbonne, in order to gain the pittance of support which enabled her to enter on her scientific training. But in the end her ability was detected and she was placed in the laboratory to conduct an investigation leading to a thesis, and as it happened, under the young instructor who afterwards became her husband.

The story begins about 1860, from which time on many observations had been made on the passage of electricity through tubes from which nearly all the air had been pumped. These studies led in 1879 to the discovery of the cathode rays of Sir William Crookes and in 1895 to the discovery of X-rays by Röntgen. A year later, or to be exact, on March 7, 1896, Becquerel, who was studying the general behavior of phosphorescent bodies, examined uranium and its compounds, and discovered that these substances gave off rays which re-

[2] Vallery-Radot, The Life of Pasteur, Eng. Trans. Vol. I, p. 50.

sembled the X-rays in their action on photographic plates. He also made the extremely important observation that the rays "ionized" the air about them, or converted it from an insulator to a conductor of electricity. A gold-leaf electroscope, which had been previously charged with electricity so that its two leaves diverged, was discharged, with the consequent collapse of its leaves as soon as uranium was brought near it.

The comparative ease and rapidity and metrical character of this method of examination induced Madame Curie to take as the subject of her doctorial thesis the measurement of the radioactive powers of an immense number of minerals, and so led her gradually to one of the most brilliant and striking discoveries of modern times, the whole representing a new epoch in our knowledge of atoms and therefore in physico-chemical science.[3] Her initial momentous observation related to the mineral pitchblende from which uranium is extracted, and which she found to be four or five times as radioactive as uranium itself. There was, of course, but one possible conclusion: the mineral contained another active element more powerful than uranium. At this point her husband joined in the quest and the mineral was converted into fractions, each of which was tested electroscopically. The bismuth fraction showed the presence of a powerful radioactive substance finally separated, and in honor of Madame Curie's native country called polonium; but it was the barium fraction which was most active and which finally yielded a salt of the new element called radium. Thus it was in 1902, or after four years of arduous and inspiring work, that the researches leading to the doctor's degree but also unlocking a new door in physics were brought to a temporary conclusion, and it was not until 1910, as you know, that Madame Curie actually obtained the element radium in a pure state. It is of some interest to recall that the radium salt proved 2,500,000 times as active as the uranium, the point from which her studies started.

Honors flowed in upon the discoverer. In 1903, she shared with Becquerel and her husband the Nobel prize. Then in 1911, after the isolation of pure radium, she was a second time awarded that great prize and in the words of the President of the Swedish Academy, was the first laureate to be awarded this distinction twice as "a proof of the importance which our Academy attaches to your discoveries * * *." And yet, because she was a woman, the French Institute declined to elect her to membership and the five French academies voted in favor of upholding "an immutable tradition against the election of women which it seemed eminently wise to respect."

Great discoveries never stand isolated and hence it frequently hap-

[3] Lodge, Oliver, op. cit.

pens that their main effect is to set into motion as by-products, secondary or new lines of research, the significance of which often eclipses the great discovery from which they took origin. Hence to-day it is especially in atomic physics and then in biology that the fructifying influence of the investigations in the field of radioactivity is noteworthy. It has happened that new and unimagined forces have been released suddenly for experiment and placed in the hands of the physicist and the biologist. I am not capable of giving an account of the latest experiments on atomic constitution which are being conducted with radium, and I stand filled with wonder and admiration as I read that the rapidity of the α-particle or helium atom derived from radium is about 20,000 times the speed of a rifle bullet, and that the energy of this motion is such that an ounce of helium moving with the speed of the α-particle is equivalent to 10,000 tons of solid shot projected with the velocity of 1000 meters per second. After having been stunned by this statement, I can well imagine that the charged particle is able to penetrate deeply into the structure of all atoms, built up as they are now believed to be on a plan similar to that of the solar system with a central sun or nucleus, and a system of planets in form of negative electrons, and to pass through as many as 500,000 of them before being deflected and turned back, and thus made to divulge the secrets of the electric fields near the center or nucleus of the atom.

But I may be somewhat better able to explain the present status of biological research being carried out with radioactive substances derived both from X-ray and from radium. The studies are proceeding in two directions: the one being of theoretical and the other of practical nature. The latter excite the greater interest because they are already rendering a highly useful service, as in the treatment of a certain class of cancers and in reducing excessive amounts of lymphatic tissue, even including recently the ubiquitous enlarged tonsils and adenoids. And yet, the former may in the end be of surpassing value in that they will serve to explain the manner in which radioactivity brings about the biological effects noted, and the means by which those which are desirable and useful may be intensified and those which are undesirable, because harmful, may be minimized or avoided altogether. Already we have learned that the radiations act quite directly on the lymphoid organs and, according to the amount or dosage employed, either stimulate to over-activity or bring about destruction; while the action on cancerous tissue is more indirect and bound up, in part at least, with the impression made upon the lymphatic system. But what I especially desire to emphasize is the connection which this class of investigations has established between the physicist and the biologist. It happens that neither alone can compass the entire field; the one is

too little a physicist, the other too little a biologist in order to manage on the one hand the rays and on the other the tissues. Together they make a working team, and already a new division of research in biophysics is beginning to appear to herald that co-operation in scientific research which is to-day one of the necessities as it is the harbinger of progress.

It should now be apparent how impossible it is for mere accident to yield a discovery in science. Whether the investigator move in the lower or the upper realm of experiment and observation, there are demanded as a minimum, knowledge of fact and familiarity with method, with which not even the most fortunately circumstanced are naturally endowed. Environment and possibly heredity also play parts, sometimes highly important parts, in giving the impulsion which leads into scientific careers and accomplishment. Moreover it is a mistaken notion to suppose that the scientific intelligence can only be and always is trained in school or college as ordinarily defined. The history of science indeed contains illuminating pages recounting the successes of men without any real formal education who have surmounted all difficulties and written their names large in its story. Such a man was Michael Faraday, of whom it has been said that of all the men who have spent their lives in the search for experimental discoveries, no one has ever approached him in the number, variety, or the importance of the new facts disclosed by his labors; and yet he was led into the pursuit of science by reading the books which passed through his hands while he was a bookbinder's apprentice.

Hitherto it has been men rather than women who have chosen the scientific career, and up to now the shining names on the banner of science are those of men and not of women. It could not have been otherwise; but now that the doors of opportunity have been thrown widely open to women, one may expect that many more will pass their portals and enter upon the career of science. Already they are feeling its lure and perceiving their aptitudes. But the lesson can not be enforced too emphatically that whether science is entered by the front door of the college or by the back door of the amateur or apprentice, in the end the material and means of science must be mastered if the votary aspires to enter paths never trodden before. To acquire that mastery to-day is no small undertaking, since the subject matter of the sciences is so voluminous and the methods often so intricate and precise. But there is nothing in my opinion in either which the trained intelligence can not grasp and the trained senses execute.

I do not recognize a line of demarcation between the sciences which men on the one hand and women on the other should choose as a career. With women as with men what should count are taste and aptitude and opportunity. It is common experience to find that a man

is directed or diverted into a given scientific field by accidental circumstances: a book falling into his hands at a critical moment; a particularly inspiring teacher who, like radium, transmutes his pupils as that does the elements; a region favorable say to geological study; a parent or other person with whom the impressionable child chances to be thrown. Once fairly launched on a career, the native ability determines the rest, just what particular road is followed and how far the traveller is carried along the road.

Even earlier influences may come to play a deciding part in directing the will and bent of the child. It does not take special insight to discern the differences in the intellectual atmosphere surrounding boys and girls in the home. While the girl is complacently occupied with dolls and miniature dressmaking and millinery, the boy's imagination is being excited by mechanical toys which his aroused interest impels him to destroy, in order that the inner mechanism may be laid bare. This is the period at which a youthful Galileo and Newton will construct windmills and water clocks, and a future Herschel, aided perhaps by another sister Carolin, will fashion some sort of optical device, the forerunner of his first telescope.

Then also custom and habit will determine that the father himself on science bent will endeavor to communicate his taste to his son rather than to his daughter. It took three generations of the Becquerel family, all concerned with the study of light phenomena, to produce the discoverer of spontaneous radioactivity. Charles Darwin's son and now his grandson are pursuing at Cambridge with distinction the related fields of mathematical astronomy and mathematical physics. Perkins, the discoverer when only seventeen years of age of the aniline dyes, has been followed by a son, the eminent professor of chemistry at Oxford; and father and son of the Bragg family have recently shared the Nobel prize for discoveries in physics.

The examples might be multiplied in which because of custom the boy, but not the girl, has been subjected to influences extending over many years calculated to prepare or to lead him, if only insensibly, into the paths of science. Moreover, the boy has other advantages to guide and spur him on: once launched on a scientific pursuit, he looks forward to a life's career and indulges the hope, if not the expectation, of being attended by some good woman. Now women have not yet been offered anything approaching a like opportunity to that put before men. The scientific career means too often for them, if consistently pursued, the denial of domestic companionships and compensations which men easily win and enjoy. In how far this condition alone will operate to bar women from the higher pursuits and greater rewards of a scientific career only experience can show. But as one who would write himself down a lover of opportunity for women, I wish to ex-

press the hope that the difficulty may not prove insurmountable. Already in this country and in two fields of which I have personal knowledge, Doctor Florence Sabin of the Johns Hopkins Medical School and Doctor Louise Pearce of the Rockefeller Institute for Medical Research have made themselves authorities in their respective branches of medical science. The latter has recently carried out a difficult mission to the Belgian Congo in connection with African sleeping sickness, such as formerly would have been entrusted to a man.

A last word. I have not spoken of the rewards of the scientific career. As with other intellectual pursuits, they are to be reckoned only partly in the coin of the country. Science is now so far developed in the United States that in college, research institution, or industry a competence can readily enough be found. In the end the greater reward will be an inner satisfaction and happiness arising out of a conscious mastery of a field of human endeavor. But for this there must be a real mastery such as comes not easily but only after a period of years and as a result of a seriousness of purpose and a concentration of effort which alone devotion to a high cause will insure.

THE MESSAGE OF THE ZEITGEIST

By Dr. G. STANLEY HALL
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THACKERAY wished he could have been Shakespeare's bootblack, and many English men of letters rank the Elizabethan above the Victorian age. Classicists have often wished they had lived in the day of Plato or Caesar, as if their age were superior to our own. F. W. Robertson said he would give all his life in exchange for an hour's talk with Jesus just after the Sermon on the Mount. Ruskin, William Morris and their group, since we can not turn the wheels of time backward, would reconstruct our own industrial and social system on the pattern of the ancient guilds. For good Catholics, the apical blossom of the Tree of Life was found in the apostolic, patristic, or scholastic period, and all that has happened in the world since is of really far less import. For Max Müller, the life of the primitive Aryan; for Schliemann, that of the Homeric age; for Tacitus, the ancient Germans, were nearest the ideal, while for Plato the golden age was in the lost Atlantis and belonged to another era.

Christianity first in its doctrine of a millennium began the new fashion of looking to the future for Utopia when we seek to escape the pressure of present reality, and to this tendency evolution has now given a great impulse, as seen in the writings of Bellamy, H. G. Wells, Pataud and Pouget, C. W. Woodbridge, Chapman, Cramm, Howe, Tangent and many other portrayers of the great and glorious things yet to come on earth or yet possible. For those who abandon themselves to such reveries, the present seems preparatory for something greater, if not again, a trifle mean compared with Altruria, Equitania, Sub-Coelum or even Meccania. During and since the war there has been a great revival of interest in what might, could, would, or should be, often in some vague or obscure place, perhaps at a time no less indeterminate, and sometimes our El Dorados have been projected to the center of the earth or to another planet—Mars—Saturn, etc.

Now, my thesis is that all such fugues from actuality and what Desjardin made supreme, *viz., le devoir présent,* are now as never before in history, weak and cowardly, flights from the duty of the hour, wasteful of precious energy, and, perhaps worst of all, they are a symptom of low morale, personal or civic, or both. True greatness consists solely in seeing everything, past, future or afar, in terms of the Here and Now, or in the power of "presentification."

The equivalent of everything that ever was, is, or can be made to happen, is not far off or in some other life, age, or place, but within or about us. Creative processes take changing forms, but the energy that impels them is identical with that which started cosmic evolution. All the Hebrew prophets did and said, we now know was inspired by the needs of the hour in which they lived, and they never strove to foretell the far future. Our time is just as ripe for a true Messiah as when the Star of Bethlehem appeared, and a new dispensation is just as needed and just as possible as when the Baptist heralded the advent of the greatest of all "presentifiers." Now, when all human institutions so slowly and laboriously evolved are impugned, every consensus challenged, every creed flouted, as much as and perhaps even more than by the ancient Sophists, the call comes to us as it did to Plato (all of whose work was inspired by the need he felt of going back to first principles) to explore, test, and if necessary reconstruct the very bases of conviction, for all open questions are new opportunities. Old beacon lights have shifted or gone out. Some of the issues we lately thought to be minor have taken on cosmic dimensions. We are all "up against" questions too big for us so that there is everywhere a sense of insufficiency which is too deep to be fully deployed in the narrow field of consciousness. Hence there is a new discontent with old leaders, standards, criteria, methods and values, and a demand everywhere for new ones, a realization that mankind must now reorient itself and take its bearings from the eternal stars and sail no longer into the unknown future by the dead reckonings of the past. We must find or make and ascend a new outlook tower high enough to command the whole earth and its history, and become familiar with the perspective and other phenomena of altitude, although this is perhaps the hardest of all things for our distracted, analytic, and specialist-ridden stage of culture.

In a word, the world is sick and needs again a great physician for its soul just as it does for its body (one-third of our youth being unfit to fight). Its distempers, however, we hope may prove to be those of youth and not of old age, but even if the latter, they are ominous for the maturity of the race. Many specialists have diagnosed and prescribed but they all deal with symptoms, and the real nature and true cause of the disease still baffle us. It may well seem preposterous to the whole guild of doctors for a layman in everything, whose only advantage is his aloofness from all their works and ways, to suggest a deeper cause demanding a more radical therapy. In what follows, however, I shall venture to attempt nothing less than this. Underlying almost everything else is the fact that man has now filled the whole earth and that it will soon become even too full of his species. The human population has in nearly every nook of the globe been increasing in the last few generations at a prodigious rate, and its pressure upon the means of subsistence is already in many regions more acute than even

Malthus foresaw. In this country almost within the memory of men now living, not only the Pacific coast but even the great Mississippi valley has been filled with a teeming and enterprising population. In 1890 some of the great powers doubted the advantage of extensive colonies in remote regions, but since the great land scramble in the decade that followed, about every part of the inhabitable earth has been appropriated, explored, and is now being exploited. All Africa is apportioned, and not only Australia but Madagascar, Borneo, New Guinea, and all the smallest of islands opened up so that there are not only no new continents but practically no new acres to be discovered. The great era of diffusion and tenancy is practically ended. Man has not only taken possession of every room but of every closet of his terrestrial habitation.

In this expansion he has been wasteful of material resources to a degree so prodigal that we can now approximately date the exhaustion of many of them. Prospecting has been so extensive and careful that there will probably be no more great new finds of gold, silver, diamonds, coal, natural gas, etc., like those of the past, and the lure and glamor of great new openings thus made is already abating; while the acreage that once yielded bumper crops without fertilization is losing its spontaneous fertility.

The moral of all these trite facts is that henceforth the progress of the world must depend upon quality, not quantity; trust more to nurture and less to nature; realize that it can reap only where and what it has sown; must row where it has hitherto drifted with the current. This country especially has grown to be the richest and greatest in the world by its natural resources, but it must henceforth not only conserve but laboriously cultivate. We have found that hereafter we must make and can not expect to find our ways. And no less important is the development of our human quality.

In the geologic history of the globe the great epochs have been marked by the alternation of two periods: first, that of the emergence of vast areas of land from the primeval sea and its tenancy by species which populated it from the ocean, adjusted themselves to terrestrial conditions, and found a table spread for them so rich that they multiplied, varied, and spread with great rapidity. Then the tides turned and there were long periods of submergence and reduction of land areas during which many forms that had established themselves upon terra firma went back to their first love, the sea, like whales and dolphins; dwindled to insignificant size; or became extinct, like the great saurians, because they could not adapt to a new habitat. What makes our age great beyond all historic comparisons is that it has seen within the last few years the high tide of man's great processional over the earth and also the beginning of the recessional ebb when the world must have a new type of both men and measures or else revert to a more primitive stage of

civilization. Already we see about us many alarming signs of regression. The great war itself, which marked so signally the turn of this all-dominating tide in human affairs, was only the inauguration of the colossal conflict between the old forces that expanded and the new ones now in the ascendant that would redirect the progress of man by adjusting to the new turn of fate.

If our planet had doubled in size while it has doubled in population; if a vast, rich, new continent had just been discovered, as in 1492, or emerged from the sea; if the population of Europe had remained what it was in the days of Napoleon; if man's wants had not increased or the standards of living risen or surplus products and foreign markets had remained unknown, and there had been no surplus population anywhere, Germany would never have had her mad dream of subjecting Europe, for the world war marked the first impact and repercussion of the great current of expansion, which had behind it the whole momentum of cosmic evolution upon material limitations. Thus man has in a sense outgrown his world, so that it is now too small for him. From now on development must be intensive rather than extensive, and inward as well as outward.

When a ship is wrecked on a savage island, passengers and crew are thrown back to primitive conditions and adapt to a new environment and adopt new leaders, and often reverse all conventional discriminations; and Bolshevism is only an ostensive paradigm of what the *Zeitgeist* is doing, only more slowly and comprehensively, for the world, which is being thrown back to first principles, and finding these to be no longer political but chiefly economic and psychological so that even its past history has to be rewritten with a new perspective.

If the wealth of any land were equally divided, everybody would be poor, not rich, and there is not wealth enough in the world to satisfy one one-hundredth of the present demand for it. As civilization advances, it costs not only more money, but more time and effort to keep people happy. Thus there is a rapidly growing excess of demand for pleasure over the supply, so that the volume of discontent is constantly mounting. This life, which is all man now really believes in or cares for, can not begin to give what he asks of it. The average individual now never thinks of the far future of the world or even of his own posterity for more than a generation or two, but wants all that is coming to him now and here, and uses every means in his power (fair and sometimes foul) to get it. Thus he plunges on toward the bankruptcy of his hopes in their present form and sagacious minds are now realizing that humanity can never be satisfied save by restricting its desires or by transforming and re-directing its aspirations to more attainable goals; or, in more technical language, by finding more internal surrogates for their gratification.

This means nothing less than that the world is now squarely up against the problem of getting a deeper knowledge of human nature and finding more effective ways of guiding it or of refitting Teufelsdrock's institutional clothes to his person, if not getting him a new suit. We must not forget that while our industrial system is less than two hundred years old and even our political institutions go back only a few thousand years, man is at least a hundred thousand years old, and that we must readjust to all better knowledge of him, just as we do to all the newly discovered laws of nature. Thus as man has reached and rebounded from his geographic and other limits, his ideals of material prosperity have also impinged upon adamantine limits, and the current of his psychic evolution must now finally make a new way in another direction. Just as there are now countless individuals who should never have been born and who could in no way so benefit the world as by taking themselves out of it (but who will never do it, so that society and industry must find ways of utilizing them as best they can, trusting the slow processes of evolution to better the human stock), so there are innumerable spurious hopes, ambitions and aspirations which should never have arisen, but which we must learn to utilize and sublimate, striving slowly to subject opportunity to social and human aims.

Nature and Man—there is nothing else outside, above, or beyond these in the universe, and there never was or will be anywhere any item of creative or conservative energy or influence either in nature or mansoul that is not just as active here and now as it ever was or will be anywhere.

The way down the long scale from cortex to cord or even from man to mollusc is as broad as the way up is straight and narrow, and many there be that walk therein. The lowest sixth of the population of England, we are told, produce one-half of the rising generation, and infra-men breed a hundred times as fast as really eugenic super-men. The forces that make for human degeneration were never so many, so active, or so ominous, and nothing less than civilization itself is at stake. It has never entered into the heart of even pessimists to conceive what might happen if anarchy should prevail. But as Christianity came in to save the world when Rome and the ancient order fell, by proclaiming immortality, so now the idea of plasmal, which comes by better breeding, and of influential immortality, that saves by contributing new knowledge and power—these constitute our only hope of salvation. The promise is to those who seek, knock, ask, and is still open to the investigator, who is its true heir.

Man had a most insignificant origin—a finger-long worm with a withy spine; then a timid, tiny frugiverous creature for whom there was no safety save in trees. Then there was a long and doubtful struggle whether he or the great carnivora should be lords of creation

for he was few and his enemies many. But during all this time he was acquiring unprecedented power of docility and adaptation, and the evolutionary urge focussed on his species as its own chosen son. For ages, too, he quailed before creatures of his own imagination which he fancied real and potent, and only now is he beginning to realize that he is truly supreme in all the universe we know, and that there is nothing above or beyond him. Thus progress consists solely in the subjection of nature to man and of his own instincts to reason and his selfish interests to the common good, and man sees his destiny, which is to rule the world within and without by the power that comes from knowledge. He must go on learning to control where he has been controlled. This is his vocation as man. As the development of erectness and of the hand, which could grasp the club and impel the point of flint first made him man, so now science is both his organ of apprehension and his tool by which he must make his sovereignty complete, come fully into his kingdom and make his reign supreme. Thus, again, we see that research is his highest function. He is and always has been the investigator *par excellence*, and now he sees his calling and election more clearly, and in the new era which is upon us he has new and unprecedented motivation for mobilizing all his energies to make his title of conquisitor clear.

If the spirit of research be the Paraclete, the native breath and vital air of all true leaders in the world now being born, we ought to know more about it. What, then, is it? It is not sufficient to say it is creation in its most modern active stage, impelled by the primal impulse by which worlds evolved out of chaos, nebulae or any other mother-lye. This is true but trite. If any kind of superman is ever evolved, and the man of the present day is destined to become a missing link like the Java man, nurture must come to the aid of nature with every hebamic art that eugenics and education can supply, even though our remote posterity be as ashamed of having sprung from us as some still are of our simian ancestry. Curiosity, seen in all the higher forms of animal life, so strong in apes and so favored by their safe arboreal life, and which harks back to the original *fiat lux*, is surely one factor in the psychogenesis of the research urge. Strong as this noetic urge is, ambition, emulation and the desire to excel is surely another factor. Perhaps the hunting and collecting instinct made their contributions to it. Philanthropy or the desire to better the estate of man and to give him command of new resources is yet another element, and this has countless lower though always beneficent expressions in the impulse to alleviate suffering and in the amelioration of the tragedy in the grim struggle for survival. But the ultimate motivation of the investigator, often deeper than his consciousness, is the will for power to dominate nature, and to make man ever more completely ruler and master of the world within and without. As man is the highest and

best and as mind is the best thing in him, so research is the supreme function of mind, the true heir of the kingdom and of all the promises. Research specializes because it must divide in order to conquer. It makes such conditions for its experiments as can be controlled and excludes all others. We refine our methods and apparatus only in order to make such answers as we can extract from the memnonian lips of the sphinx more definite and explicit. Despite its baffling technique, science is, as Vähinger long ago so convincingly showed us, the quickest and easiest way of grasping the universe.

In view of all this we must regard nothing as quite so opportune or so true an expression of the Zeitgeist as the efforts to perfect the organization of the National Research Council in this country, the British Privy Council of Scientific and Industrial Research, and the international reorganization at Brussels to the same end. There are countless new problems in astronomy, geography, geology, archaeology, anthropology, economics, and in many other fields that can be solved only by wide co-operative methods, which often also require large funds, wise administration, systematic publication of results, and the spur, which pure science in a measure always lacks, of immediate utility, for every new discovery possible must be made serviceable.

It is inspiring to be authoritatively told that whereas fifteen years ago there were only four thousand individuals in this country who could be called investigators, there are now more than ten thousand who would be called such, and also that there are yet possible "finds," sometimes of great value, that can still be made even by amateurs and non-experts whom chance or locality favor, and that more can be recruited for this army of advance by questionnaire or correspondence methods. The prospector, placer-miner, still has his place in any comprehensive survey of research planning, and this work needs a consistorium of its own.

But we must not forget that the true spirit of research at its best can never be organized or administered and that to do so suggests simony, the sin of the purchase of the gift of the Spirit with money. Its very essence is freedom, and we can no more organize it than we can love, art, literature, or piety. The investigator is a law unto himself, and he must often shatter old tables of value and propound new ones. "The spirit goeth wherever it listeth" and we can not tell "whence it cometh or whither it goeth, such are they who are born of the spirit."

Now, universities are to-day, or should be, true shrines of this spirit and nurseries of these supermen. Are they? Over two hundred of them have lately made "drives" that have brought generous and greatly needed increases of salary to their professors. Labor, too, has doubled its wage, but the complaint is universal that along with increased pay has very commonly gone a decrease in the quality and

quantity of efficient work or service rendered. The worker "sojers" more on his job, and not only the hours but the amount of work per hour has decreased; as also has the quality of many kinds of goods along with the rise in their price. The bricklayer is now penalized by his union if he lays more than one-fourth the number of bricks per day he did when his wage was half its present amount.

Are our Faculties to illustrate the same tendency? In a number of presidential reports I have lately looked over I find no word of warning against this danger, no hint that to whom more is given will more be required, no exhortation to investigation, but usually the old cry for more, ever more gifts. Not content to stand hat in hand on the street corner, academic agents and presidents appeal to every graduate, poor as well as rich, to give, until they are made to feel that they are ingrates or disloyal if they are unable to do so. These reports often complain of a great influx of students, and all our larger institutions are already too full for efficiency so that some have even forsworn new departments or set a limit to the rush of students. Two reports express the fear that the average quality of the latter is declining, and one deplores the increase of mechanism, bookkeeping, and deans' functions generally, which are necessary for the regimentation of the mob of new applicants. One very competent expert has studied the programs of the meetings of various scientific societies during last Christmas week, with the result that several show in recent years a very marked increase in the percentage of papers read by non-academic men (80% now in one of the largest and oldest of them), which is not surprising when we consider the great number of professors now being lured away from colleges and universities by larger salaries offered them to become experts in industry, which has apparently just now awakened to the need of specialists.

Now, if there is any one general lesson of these tumultuous times, any conclusion that underlies and conditions all others—as I insist there is—it may be stated very simply as follows. Henceforth, as never before, progress is committed to the hands of the intellectuals and they must think harder, realizing to the full the responsibilities of their new leadership. Science in its largest sense is from this time forth to rule the world. The age of *laissez faire* is ended and research, discovery, investigation, and invention, which have done so much already, must now take the helm and be our pioneers in this new era. In everything it is the expert who must say the final word. Thus our prime duty is to inventory and especially develop and devise every possible new way of fostering the spirit of original research in this new day that is now dawning upon the world, and in which it is the inestimable privilege of this generation to live. We can not too clearly realize or too often repeat that research is in the very center of the current of creative

evolution and has the momentum of all the developmental urge behind it. Its spirit is to the new era what the Holy Ghost was to the early church. Once it made prophets and apostles, inspired visions, sent men to waste places to meditate as hermits, anchorites, ascetics crucifying the flesh, or impelled them to challenge rulers or to become martyrs. Now it inspires men to seclude themselves in laboratories, museums, studies, libraries; sends them to remote and perhaps hostile and dangerous corners of the earth to observe, collect, excavate, decipher, reconstruct extinct animals from fossils or fragments of bones and teeth, or to restore prehistoric life from vestiges and utensils in caves, cromlechs, relics of pile-dwellers; or to reconstruct temples, palaces, dwellings, and even huts from their buried foundations; perhaps to explore the sources of mineral, agricultural, and industrial wealth; or to study and control the ways of and antidotes for new microbes, insect pests and toxins. Human culture began with the attempt of man to understand his own soul, its nature and destiny; and to this was soon added interest in his body and its diseases. Now we are studying his relations to his home and his mother, Nature, and his social, industrial, and family life.

When I lately asked my dentist why he hurt me so cruelly now when the same operation on the other side eight years ago was painless, he replied that now he had to use American instead of German novocain and we have not learned to make the pure article. In looking over Kahlbaum's catalogue of hundreds of chemical compounds necessary for every research laboratory, I was told that only a very few of them can even yet be produced outside of Germany and that our chemical industries have focussed upon nitrates, dyes, and other large-scale products that bring great profits.

Turning to other departments, ever since the Reformation German scholarship has led in all Biblical studies, giving us the higher criticism, and its preëminence has been no less in the study of classical texts and history. Our professors of philosophy have largely concerned themselves with problems of German origin from Kant to Schopenhauer and Nietzsche. Biological work has for two decades focussed on the theories of Weismann and Mendel, both Teutonic. In every psychological laboratory the name of Wundt outranks all others, while Freud has more lately given us another group of great ideas which are working as leaven not only in the studies of mind normal and abnormal, but in our conceptions of art, literature, daily life, history, and religion. Students of the exact sciences are agog over the theories of relativity as represented by Einstein and the even more revolutionary concept of quanta, also of German origin. For decades our best graduates who desired to specialize studied there and a large part of our professors have been trained there, so that the apex of our educational system was long found beyond the Rhine.

All this was in accordance with the policy laid down by Fichte only a little more than a century ago in his famous address to the German nation when Napoleon had annihilated the Teutonic armies, crushed the German spirit, and his spies were scattered through the very hall. Fichte's thesis was that Germany must become *the* educational leader of the world and must thus rehabilitate herself from bottom to top and understand that her only possible way of escaping obscurity, if not annihilation, was research, her only asset was in the truth to be discovered and new powers to be utilized. In a word, her soil was poor, her armies gone, her finances ruined, her spirit near despair, and the gospel of Fichte, the "presentifier" of his day, was that all the power she could ever expect in the future must come from knowledge—that her specialty must be in its creation and diffusion. And the world knows the result of this policy, which in a century made his country the strongest in all history, which never saw so brief and great a national regeneration in the same short span of years.

To-day this leadership is gravely impaired, and possibly forever shattered, and it is craven and imbecile not to see that the situation brings a new call to this country, now the richest and most prosperous in the world—spending more money for education, we have just been told, than all Europe combined—to aspire to this succession, to pay back our intellectual debt, and possibly to bring the keystone of the educational arch again to this country. Of course we must not forget, as Kuno Francke reminds us, that Germany in her present distress may again hark back to the gospel of Fichte and seek to renew her strength by a yet more intensive development of culture and hope to sometime achieve a new intellectual conquest of the world, such as she was so far on the way toward achieving when she turned from culture to Kultur and, at length, not content with this, made her supreme error of appealing to the sword. Of course science is universal and knows no national boundaries, but our nationality, whatever it is and is worth, has here a new opportunity undreamed of before.

Not only does democracy, if it is to be made safe for the world, require education of its citizenry much above the mental age of thirteen and a half, which was the average of our soldiers tested, (and we have even been called a nation of sixth-graders), but every land —and this most of all—is now crying out for new leaders in every department. Our statesmen need broader training in international relations and show every symptom which alienists find in all minds grappling with problems too large for their powers. Our captains of industry need to look farther afield and farther ahead. The waste of incompetency and the curse of mediocrity are upon us. We have utterly lost all power of discriminating between the best men, things, ideas, books, and the second or even the tenth best.

The psychology of the whole matter is that we love knowledge because we love power. As man has domesticated some two hundred species of animals, using for his own benefit their strength, instincts, keener senses, etc., so he strives to command the powers of nature and to really become the captain of his own soul. Competent engineers tell us that the average individual to-day commands some thirty-three man-power besides his own, whereas a century ago all inventions gave him command over only two and a half times his own strength. But ever more is and will be needed although waste also increases, and all we have known and controlled is only the beginning. Man is really only just starting on his career as an investigator so that thus research is not only the apex of creative evolution and the highest vocation of man but is the greatest joy that life affords to mortals. He who reveals and teaches us to command more of the world without and within is the chief benefactor of the race, the true prophet, priest, and king in our day.

Now, probably the university should be the chief shrine and also the power-house of this spirit, which ought to be for the new post-bellum epoch now opening what the Holy Ghost was to the early church, for in it the higher powers of man have their chief deployment. There is a final lesson from the church that we ought to lay to heart. Beside and above all its elaborate medieval organization, even when it was at the height of its power and aspired to universal dominion, its greatest leaders always felt that above and beyond it was the larger Church Invisible, eternal, not made with hands, the membership of which consisted of everybody, everywhere, who strove supremely for righteousness and truth. To-day we should give a similar place in our scheme of things to the University Invisible, composed of all those everywhere who are smitten with the passion of adding something to the sum of the world's knowledge, even ever so tiny a brick to the splendid temple of science, which is the supreme creation of man, but who realize that of this temple only the foundations are yet actually laid and that the most imposing part of the structure is not only not built but can not even be completely planned. The members of this new church of science are those who feel the call to make some original contribution of their own toward either its plan or its further structure, for the true university is, after all, only found in the investigator's state of mind. All through the history of the church, as Renan has shown, ran a faith generally submerged but which had many timid out-crops that in the fullness of time there was to come a new, third dispensation superseding the old, *viz.*, the dispensation of the Spirit. It is that into which we are now summoned to enter. Have we the virtue to hear and heed the call?

SWISS GEODESY AND THE UNITED STATES COAST SURVEY[1]

By Professor FLORIAN CAJORI

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THE influence of the intellect transcends mountains and leaps across oceans. At the time when George Washington warned his fellow countrymen against entangling political alliances with European countries, there was started a movement of far reaching scientific importance in a small country in the heart of the Alps which (as we shall see) exerted a silent, yet potent scientific influence upon the young republic on the eastern shores of North America. Our government executives can restrict the movements of troops and can abstain from making hazardous treaties, but these policies can not permanently check the subtler movements of intellectual thought which often, like aerial waves, encircle the world.

In 1785 a gifted and enthusiastic young German named Johann Georg Tralles became professor of mathematics and physics at Berne in Switzerland. Interested in applied as well as pure mathematics, Tralles was active as a metrologist and geodesist. Maps of that part of Switzerland had been altogether unreliable. He entered upon refined surveys of the triangulation type. In this work he was assisted by one of his pupils, Ferdinand Rudolf Hassler of Aarau, a young man who belonged to a well-to-do family. His father had mapped out for him a bureaucratic career which would have brought a good competence. But the mathematics and the surveying instruments of Tralles exerted an attraction impossible for him to resist. In 1791 Tralles and Hassler measured a base-line together, using a steel-chain manufactured by the English mechanic Ramsden. The base line was 40,000 feet long; its ends were marked on blocks of stone four feet high, with steel points held in position by cast lead. Not satisfied with the accuracy reached, a few years later they remeasured this base with improved apparatus. Carefully standardized rods now took the place of chains. A net of triangles was adopted, the principal points of which were the several summits of the Jura mountain range. For the great distances between stations the instruments were found to be inadequate. Tralles wrote to a friend about his angular measure-

[1] Sigma Xi address delivered at Northwestern University on December 13, 1920.

ments: "I have tortured them out with a theodolite—measurement I can not call this, when the telescope is so weak that one can not see the signals, but only guess their position. You can readily see that they are not small, for the telescope of the theodolite reveals them at a distance of 100,000 feet." The government of the Canton of Berne was appealed to for financial aid in the purchase of a more powerful instrument. Six hundred dollars were voted immediately. Mr. Ramsden in London, then the most celebrated instrument-maker living, for a sum somewhat exceeding this amount, promised to supply in 1794 a complete azimuth circle, at least three feet in diameter. Due to various delays the great instrument did not reach Berne until 1797. Meanwhile some smaller instruments had been secured from England; Tralles and Hassler had been active in perfecting their technique. Young Hassler received the commission to determine the boundary line between the Cantons Berne and Solothurn. Ramsden's three-foot theodolite was a wonderful instrument; only two other instruments of that size and precision are said to have been manufactured by Ramsden. What a privilege for young Hassler to become practically acquainted with the use of an instrument of the high type that very few surveyors then living had ever seen!

Hassler repeatedly took trips to Paris and one trip to Germany; he attended lectures and became personally acquainted with leading scientists—among them Lalande, Borda, Delambre and Lavoisier in Paris; Von Zach and Bohnenberger in Germany. With funds liberally supplied by his father, Hassler purchased many instruments and scientific books. He astonished Von Zach late one afternoon by measuring with a five-inch English reflecting sextant and mercury horizon the latitude of Zach's observatory and differing only five seconds from previously known determinations. We see Hassler occupied with serious studies and becoming familiar with the practical operation of the most refined mathematical instruments in existance at the time.

Geodetic work in Switzerland was stopped by revolutionary events. In 1798 French soldiers marched into Berne. Friction arose between Franch and Swiss goedesists. A few years passed without bringing relief. Hassler who meanwhile had married and had held various official positions of responsibility in his canton of Aargau became weary of European turmoil, and decided to seek his fortune in the New World. Strange to say we find him engaged in the organization of a stock company for the purchase of large tracts of land in South Carolina. In 1805 he departed with wife, children, servants and 96 trunks, boxes and bales, and travelled down the Rhine, having previously chartered in Amsterdam the ship "Liberty" (350 tons) for Philadelphia. He was accompanied on his trip by over 100 laborers to form a Swiss colony in the South. Unfortunately Hassler's agent speculated with

the funds entrusted to him and Hassler sustained heavy financial loss. He arrived in Philadelphia without means to support his family. While waiting for remittances from his father, he sold some of his books and instruments. He received financial assistance also from John Vaughan, a prosperous and public spirited Philadelphian.

Hassler soon got in touch with scientific men in Philadelphia. He attended meetings of the American Philosophical Society. On December 6th, 1805, he donated to this Society a model of Mont Blanc, two chamois horns, and a specimen of feldspar. Hassler was elected a member of the Society on April 17th, 1807. The year previous he had sold to the Philosophical Society "the volumes necessary to complete the transactions of the French Academy of Science of which the Society possessed eighty-nine volumes, the bequest of Dr. Franklin." Hassler sold also some volumes of the transactions of the Berlin Academy. I mention these items to indicate the kind of books Hassler brought to America.

He brought also a number of instruments and standard weights and measures, such as had never before been carried to the American shores. Among these were a standard meter, made at Paris in 1799 by the Committee of Weights and Measures, a standard kilogram, an iron toise, made by Cavinet in Paris, two toises of Lalande. All of these were acquired by the American Philosophical Society and were loaned to Hassler twenty-six years later when he was acting in Washington as superintendent of weights and measures.

In 1806, Professor Robert Patterson and John Vaughan in Philadelphia, John Garnett of New Brunswick and others were deeply impressed by the ability and enthusiasm for science displayed by Hassler. Patterson was then director of the United States Mint. Feeling no doubt that the services of this talented young man of 36, whose long course of special training secured in Switzerland, France and Germany, made him one of the very foremost living practical geodesists, should be enlisted by the American Government, Professor Patterson gave President Jefferson an account of Hassler's life. "He would willingly engage," said Patterson, "in an exploring expedition, such as those you have already set on foot."

As neither Patterson's letter to President Jefferson, nor Hassler's brief autobiography enclosed with it, has ever appeared in print, it may be interesting to present these documents, at least in part.[2] Professor Patterson wrote:

[2] For copies of these documents, and of the letters written by President Jefferson and President Madison which we quote later, we are indebted to the kindness of Dr. Anita Newcomb McGee of Washington, D. C. The originals are in the Manuscript Division of the Library of Congress. Dr. McGee is a great granddaughter of Hassler.

(From Robert Patterson, Director of the Mint, to Jefferson.)

Philad. March 3d 1806.

"Sir

"I beg leave to introduce to your notice Mr. Hassler, a gentleman lately from Switzerland. He is a man of science & education; and, as will appear from the enclosed paper, written by himself at my request, was a character of considerable importance in his own country. It is his wish to obtain some employment from the United States, which would require the practice of surveying or astronomy. He would willingly engage in an exploring expedition, such as those you have already set on foot; for which, I have no doubt, he would be found well qualified.

"In his education he paid perticular attention to the study of astronomy, and statistical surveying; & from the enclosed paper you will see, that he is well versed in the practice. He is a man of a sound, hardy constitution, about 35 years of age, & of the most amiable conciliating manners. Besides his knowledge of the Latin language, he speaks the German, French, Italian & English. To his acquaintance with mathematics in general, which, as far as I am capable of judging from a short though not slight acquaintance, is very extensive, he adds a good knowledge of chemistry, mineralogy, and all the other branches of natural philosophy. In short, Sir, I believe his services may be rendered useful to this his adopted country. He possesses a very valuable library, and a set of surveying & astronomical instruments, scarce inferior to any I ever saw.

"I shall only add, that the cause for which he struggled in his native country, and the reasons for his seeking an asilum here, will not, Sir, I am sure, detract from his merit in your estimation.

"I have the honour to be,
"with sentiments of the
"greatest esteem,—
"Your most obedient servt.
R. Patterson.

"P. S. I forgot to mention, that Mr Hassler is at present settled with his family (a wife & three children with a few domestics) on a small farm near the banks of the Schuylkill, and that he proposes very shortly to pay a visit to the seat of government."

Hassler's sketch of his life which was enclosed in the letter that Patterson sent to President Jefferson, is reproduced here with all its orthographic peculiarities:

"Feb. 27, 1806.

"After my first education in public and private schools at Arau, my native town, I went in my 16th Year 1787 as a Voluntary in an

office of the government of Berne, appointed for all kind of surveyings and the care of the archives of the state, in which businesses I worked; following at the same time the lessons of the College, then newly established under the name of political institute, and the private instructions of Mr. Tralles Professor of Mathematics, (now member of the Academy of Berlin) aplying chiefly to practical geometry & astronomy. As a practical exercise of these instructions Mr Tralles & I undertoock in 1791. (on my expenses) the trigonometrical mesurements for a map of the country, and mesured a base of 7¾ Miles length and some triangles, with proper means and instruments, till the season interrupted the further prosecution.

"The Government of Berne, seeing the various advantages of this Work, undertook to follow it, and appointed proper funds for the instruments; which were comitted to Mr Ramsden in London.

"In 1792 I went to the university of Göttinguen, (staying a short time in my passage at the Observatory of Mr de Zach at Seeberg) where I continued my studies in mathematics and natural Philosophy, under Kästner and Lichtenberg; (with whom I was particularly acquainted): Obliged nevertheless by the wishes of my father, to give some time to the study of Diplomatics under Gatterer.

In 1796, I went to Paris applying half a Year chiefly to Mineralogy & Chymistry under Haüy, Vauquelin, Fourcroy &c. (being already acquainted by a former Voyage there with LaLande & Borda.)

In 1797. a large Theodalite of Ramsden beeing arrived at Berne Mr Tralles & I endeavoured to prosecute now for the Government the Geographical Operations begun in 1791. but ware soon stoped again by the Revolution of Switzerland early in 1798. which event changed at the same time my position by annulating a post of my father the succession of which was secured to me since my 16th Year.

Though the ministry of Finances of the Helvetic Republic, desireous of an accurate mape of the country gived me on a new the commission to follow the Work and I worked at it a short time in 2 Seasons the perpetual changes & finally extinction of the unitary Government put an end to this Work for which I could neither get my advances repayed nor my Labour. On my leaving the Country I left the unfinished Work to one of my friends to be sold for a trifle to the new Government.

Though I took no trouble to get any public office I was early in 1798. elected to the Court of appeal of the Canton of Argovia for the direction of criminal affairs, (accusateur public) from which place I was called in 1799. by the Central Government to the same functions at the Supreme Court of the Helvetic Republic, after the extinction of which in 1803, I went at home were I was elected by the representatives of the Canton a member supleant of the Court of Appeals, and by my

fellow-Citizens a member of the Counsel of the town, in which I was trusted with the chief Direction of public buildings and Archives.
But foreseeing the constant oscillations in the state of the Country involving always my position according to past experiences (intrigues and ambition, which are wanted in such circumstances, beeing out of my Caracter) I took with some of my friends the resolution to come over to America in search of more solidity in a peaceable Country.
Though I shall be one of the Directors of a Society of my countrymens intending to come over in this Country my presence beeing not always nor absolutely wanted, I could and wished to be employed in some business where practical Geometry & Astronomy would be the requisites, by preference.
Philadelphia 27th Febr: 1806: F:R:Hassler."

In addition to Professor Patterson's letter and enclosure, President Jefferson received a letter from Dr. C. Wistar of Philadelphia, recommending Hassler. President Jefferson's reply to Dr. Wistar, which has never been printed, is as follows:

"Yours of the 19th, [February 19th 1807] has been received, as was a former one proposing Mr. Hassler to be employed in the survey of the coast. I have heard so much good of him as to feel a real wish that he may find the employment of the nature to which his physical constitution & habits may be equal. I doubt if. in yielding this as to Mr. Hassler, I transgress a principle I have considered as important in making appointments. The foreigners who come to reside in this country, bring with them an almost universal expectation of office. I recieve more applications from them than would fill all the offices of the U. S. * * * It is true there are some employments * * * into which meritorious foreigners & of peculiar qualifications may sometimes be introduced. such is the present case."

It appears that the starting of the survey of the coast of the United States was taken under consideration by members of the American Philosophical Society at Philadelphia for the reason that there had come into their midst a man preeminently qualified to undertake such a survey. In other words, had Hassler not come to the United States, probably no effort would have been made at that time to organize such a survey. Upon President Jefferson's recommendation, Congress passed a law, authorizing a survey on February 10th, 1807, and made an appropriation of $50,000. Albert Gallatin, Secretary of the Treasury, addressed a circular letter to scientific men, asking for plans for carrying the survey into effect. Among the replies were letters from Robert Patterson of the U. S. Mint, James Madison, then President of William and Mary College, Andrew Ellicott who had long been active as a surveyor in the United States, John Garnett of New Brunswick who

was interested in astronomic and geodetic affairs. Hassler's reply was written in the French language; it carefully outlined a trigonometric survey and the use of chronometers in localities where trigonometric surveys would be very difficult. At President Jefferson's direction, a commission passed upon these plans. That Hassler's plans would be chosen seemed to be a foregone conclusion in the minds of most scientists interested. The commission was formed of the very men who had submitted plans, with the omission of Hassler, who was then at West Point. In rejection of their own plans, they recommended Hassler's. On account of political disturbances in Europe and America the survey was not begun in 1807. Meanwhile Hassler had been appointed acting professor of mathematics at West Point, where he served two years. Later he was for one year professor at Union College at Schenectady.

During his residence at West Point and Schenectady he had occasional correspondence with Patterson regarding details for the coast survey, especially the necessary instruments. On September 2, 1807, Patterson asked him by letter whether he would be willing to go to London to direct the construction of the instruments there. Hassler expressed his willingness to undertake the mission, but not until August, 1811, was the government able to send him. Hassler embarked with his large family for England.

After the death of Ramsden, Edward Troughton came into ascendency as a skilled mechanic. It was his ambition in life to surpass Ramsden as an instrument maker. Hassler set Troughton and others to work, manufacturing under his direction instruments for the United States Coast Survey. Some of the principal instruments were of Hassler's own design. He secured instruments and books also from Paris. Politically the time was unfavorable; the war of 1812 broke out. Hassler was in the country of the enemy. Once he was refused a passport in London until after a personal application was made to the foreign secretary, who granted the passport with the generous remark "that the British Government made no wars on science."

The total amount expended for instruments during four years in England and France was $37,500; including books, Hassler's salary and travelling expenses, the outlay exceeded $55,000. Troughton, the celebrated London instrument maker, remarked that there was not so complete and useful a collection of instruments in the possession of any government in Europe.

On October 16, 1815, Hassler informed Mr. Dallas, then Secretary of the Treasury, of his safe arrival with the instruments, in Delaware Bay; they were deposited at the University of Pennsylvania. Some of the instruments were intended for use in two astronomical observatories that were to be established according to Hassler's plans which

had been matured some time in the interval 1807-1811. He brought back all the instruments then deemed essential for the astronomical observatories except a mural circle and zenith sector, which he "did not venture to order, as their absolute necessity, in connection with the survey of the coast, was not so obvious as that of the instruments procured."

"To procure the greatest advantage to the survey," continued Hassler, "their positions [positions of the observatories] should be as far North East and South West as the very favorable position of the United States admits"—one in the district of Maine, the other in Lower Louisiana. "Nearly every celestial phenomenon observable from the tropic to the arctic circle and within about two hundred degrees of difference of longitude, could be observed at one or the other of them." Little did Hassler realize at that time that over a quarter of a century would elapse before Congress would authorize a national astronomical observatory.

Not until May 2, 1816, did Congress pass appropriations for the survey of the coast. In August of the same year Hassler was appointed Superintendent of the Survey of the Coast. In his eagerness to begin work Hassler had gone to Long Island and reconnoitered the neighborhood during the month before his regular appointment. At first he had only three inexperienced cadets from West Point to help him; in September, Major Abert, one of his West Point acquaintances, was detailed to assist him. Great difficulty was experienced in finding a satisfactory locality for the measurement of a base line. Bad weather caused further delays. Once his work was interrupted by a law-suit brought by a man who charged that Hassler had cut off some branches of a cedar bush, to make the remaining part of the bush answer as a temporary signal. There were no railroads in those days; public highways were few. Hassler's work took him to localities not easily reached. For conveying of himself, his men and his delicate instruments, he had constructed early in 1817 a spring carriage, of special design, to be pulled by two or four horses. This carriage became famous because of its odd appearance and because political opponents of Hassler charged that he indulged in luxurious travel, such as was enjoyed by no other government official.

Delays occurred also because of tardiness on the part of the Government in sending the necessary funds. At times Hassler advanced money of his own, to prevent interruption of the work. The difficulties experienced from wooded marshes and the absence of sharp points near the coast made it necessary for him to plan for a full chain of triangles back from the shore. The proper locality for a base was not found until April, 1817. In February the Secretary of the Treasury asked Hassler to state the probable time required for the execution of the

survey. This was a disquieting question; as yet, the survey had hardly begun! In the Canton of Berne, Switzerland, four years had been considered none too long a period for a much smaller project. With Major Abert as his only trained assistant, Hassler worked during 1817 from the opening of the season in April until the end of December, when none but Hassler "thought it possible to stand it any longer" on account of the cold. He worked early and late, whenever weather permitted, and displayed an enthusiasm seldom equalled. At that time Hassler knew little about American politics. He proceeded on the supposition that if he maintained high scientific standards, if he worked hard and faithfully, his services would be appreciated. He learned by sad experience that this is not necessarily the case, that the head of a government scientific bureau must take pains to keep in touch with political leaders and through personal contact and courtesies extended must endeavor to secure the interest and good will of these leaders; in other words, that political leaders must be educated to the appreciation of science. Hassler did not work in Washington at that time. In winter, when work in the field was impossible, he resided in Newark, New Jersey. Even if he had tried, it would have been difficult to have kept in touch with Congressmen.

In 1817 eight triangles were formed, determining the distances of about forty points with great accuracy; two bases were measured; latitudes and azimuths were ascertained. After December, the winter was passed in performing the necessary computations. On April 6, 1818, the Secretary of the Treasury apprised Hassler of the fact that the little progress made in the survey had caused general dissatisfaction in Congress. This was a bolt from an almost clear sky. Hassler replied by telling what had been accomplished—more than double what had been achieved in the English survey in the same time. After sending this reply, Hassler, who was in Newark, concluded that he had better go to Washington with all his documents, so that he could offer any explanation desired. His explanations to the Secretary of the Treasury were of no avail; on April 14, 1818, the law authorizing the survey was so modified by Congress as to exclude Hassler, a civilian, and leave the survey in charge of military and naval officers.

The fundamental difference between Hassler and Congress was that Hassler aimed to make a triangulation survey that would be a credit to America in the eyes of scientific men of the world; such a survey requires time. Congress, on the other hand, had no intention of aiding science; they wanted a map of the coast and that without delay.

Terrific as this blow must have been to Hassler, he took it calmly. Defeats never subdued him; they spurred him on to renewed efforts. Krusenstern wrote him from St. Petersburg, "In Russia your talents would have been better appreciated."

For fourteen years nothing creditable was done on the coast survey. No one connected with it had the training, experience and vision to carry it on successfully. These years constitute the dark ages of the United States Coast Survey.

For Hassler these fourteen years from the age of 48 to 62 should have been scientifically the most productive years of his life; but eleven of the fourteen were the most barren. We pass in silence his years of struggle to support his large family, years during which the operation of a farm in northern New York proved financially disastrous, years during part of which his energy was dissipated by school teaching in small private academies and in the compilation of elementary text-books; years of mental anguish over the breaking of family ties. I may add parenthetically that Hassler had nine children, several of whom died in childhood. Hassler's eldest son has many descendants in this country. Hassler's son, Charles Augustus, was a surgeon in the U. S. Navy and was the father of Mary Caroline, wife of the late Simon Newcomb, the astronomer. Mrs. Newcomb is now living in Washington.

In 1830 Hassler was placed at the head of the work of weights and measures—a scientific department of the Federal Government organized by him. His ten years of preparation in Switzerland and his trips to France and Germany fitted him admirably for such work. Finally in 1832, when Hassler was 62 years old, Congress experienced a lucid interval and re-enacted the law of 1807 on the Coast Survey. Hassler was reinstated as superintendent. For eleven years he labored assiduously, until death claimed him. During that time the Coast Survey advanced with rapid strides, notwithstanding continual interference by government officials and members of Congress.

Hassler remained mentally alert to the very last. He kept in touch with geodesists and astronomers of Europe. He was in correspondence with Gauss of Göttingen. He was in touch with Bessel who wrote a critical yet very appreciative review of Hassler's description of his plans and instruments for the U. S. Coast Survey, printed in 1825. Bessel saw in those plans original features which placed them higher than any plans then in operation in other countries. Hassler was in regular correspondence with Schumacher, the editor of *Astronomische Nachrichten;* with Admiral Krusenstern and the elder Struve in Russia; Hassler communicated with the astronomer Tiarks and with Edward Troughton in England; occasionally he contributed papers to European journals. He was an associate of the London Royal Astronomical Society. In our country he kept in correspondence with Thomas Jefferson and James Madison. Thus, instead of living a submissive, passive life, instead of vegetating, he kept his mind alert, young and creative.

The reader may be interested in an unpublished letter which ex-

President Madison wrote Hassler on February 22, 1832, when Madison was in his eighty-first year:

Montpelier, february 22, 1832.

Dear Sir:

I have received your favor with the accompanying copies of your report on weights and measures. I have forwarded the two, one for Professor Patterson and one for the University of Virginia, and shall dispose of the others as you desire. For the copy allotted to myself, I return you my thanks. The decrepit state of my health, added to my great age and other causes, have prevented me from looking much into the work. My confidence in your aptitude for it, takes the place of a positive proof of its merits.

I am glad to learn that you are to resume the important labor of surveying the coast. I hope you will be able to complete it; and to your own satisfaction, in which case I doubt not it will be to the satisfaction of those who invite you to the undertaking.

I tender you sir my esteemed friendly salutations.

(Signed) James Madison.

The creative side of Hassler is seen mainly in the design of new instruments. He put forth an improved repeating theodolite. For signals at geodetic stations, Hassler, in 1806, recommended spherical reflectors, such as he had used in Switzerland, but later introduced truncated cones of tin which could be manufactured easily and cheaply and under ordinary and easy conditions, possessed advantages over the heliotrope invented later by Gauss. Hassler appears to be the earliest geodesist who thought of using the bright reflection of solar light from a gilt ball or cone. After 1836 Hassler used Gauss' heliotrope for great distances to be pierced under bad atmospheric conditions. Most original was Hassler's base line apparatus which involved an idea worked out by him in Switzerland and perfected in this country. Instead of bringing different bars in actual contact during the progress of base-measurements, he used only one bar and *optical* contact. Each end of the bar was marked by a spider web; a compound microscope standing upon a separate support was placed at the forward end, right over the spider-web. As the place of this end of the bar was determined by the microscope the bar could be moved forward and its back end placed under the microscope. This was truly an ingenious procedure.

It is interesting that Hassler's plans for an observatory in the United States which were presented to the Government in 1816 and published in 1825 should resemble those actually carried out later by Schumacher in the Altona Observatory in 1826. From obvious principles both scientists deduced independently of one another, plans closely resembling each other.

In the making of maps, Hassler used what is now called the American polyconic projection. This projection was well adapted for the eastern coast of the United States which is a narrow strip extending ap-

proximately north and south. Mr. C. H. Deetz of the Coast and Geodetic Survey, says that "Hassler's polyconic projection possesses great popularity on account of mechanical ease of construction and the fact that a general table for its use has been calculated for the whole spheroid." "It has," adds Mr. O. S. Adams, "been extensively used by the United States Coast and Geodetic Survey."

When Hassler resumed work on the Coast Survey in 1832 his health was somewhat broken, but his mind was clear and his spirit unbroken and defiant of his opponents, to the very last. "Difficulties have never subdued me in my life," "I have worked in sick days and in well days" are statements the more impressive, when we recall his struggles against poverty, the large family dependent upon him, the illness of his children, his serious family vicissitudes, the advantages taken of him by supposedly personal friends, the limitations placed upon him by government red tape, and the political attacks hurled against him. In these respects his career resembles that of the immortal Kepler.

In his struggles with government officials, Hassler insisted that for the greatest success of the Coast Survey, the Superintendent must be given liberty to hire men whenever the work required it, to arrange for transportation of instruments by land or water, the purchase of instruments and books within the limits set by the appropriations made by Congress. This liberty, said Hassler, the Superintendent of the Coast Survey should have, just as a sea-captain is allowed "to set the sails of his vessel according to the wind and sea." Hassler's signing the list of accounts with the statement "these expenses were incurred in consequence of my direction for the survey of the coast" were objected to by auditors of the treasury department as insufficient. Hassler entered a vigorous protest and in this struggle won out on many points.

A bone of contention was Hassler's salary. An anecdote became current about 1836 that Secretary Woodburry and Hassler could not agree on this point, and that Hassler was referred to President Jackson. "So Mr. Hassler, it appears the Secretary and you cannot agree about this matter," remarked President Jackson, when Hassler had stated his case in his usual emphatic style. "No sir, we can't". "Well, how much do you really think you ought to have?" "Six thousand dollars, Sir." "Why, Mr. Hassler, that is as much as Mr. Woodbury himself receives." "Mr. Voodburry!" declared Hassler, rising from his chair, "there are plenty of Voodburrys, plenty of Everybodys who can be made Secretary of the Treasury. But," said he, pointing his forefinger toward himself, "there is only one, *one* Hassler for the head of the Coast Survey." President Jackson, sympathizing with a character having some traits in common with his own, granted Hassler's demand.

One objection raised to Hassler in Congress was that his survey was too slow and expensive; a modified, less scientific, more expedi-

tious plan was advocated. As we look back now after the passage of four score years, Hassler stands out greatest in perceiving and singling out what was best in the practical goedesy of his time, in making improvements upon what he found, and then clinging to his plan, which was a triangulation scheme, as being the best that the science of his day brought forth—clinging as a mother does to her child in danger. What looms highest is his moral quality and strength to resist compromises, to resist hazardous alterations suggested by engineers and statesmen, to maintain this opposition against the adoption of "cheaper" yet "just as good" plans, and to persist in this opposition year after year, decade after decade, from young manhood to old age. The services of Hassler to the Nation loom larger and larger with the lapse of time. Hassler scorned pretensions and shams. Says a recent writer: "Due to his far sightedness the best foundation was thus laid for geodetic operations."

Switzerland, at the close of the eighteenth century, embodied in its triangulation surveys the best that European science could offer. Tralles and Hassler introduced some novelties of their own. The Swiss science and art of geodesy were carried by Hassler to the United States. Keeping in constant touch with European progress, Hassler exercised his genius in adopting European practice to American conditions and adding improvements of his own. Thus, Switzerland became the mother of American Geodesy.

THE HISTORY OF CHEMISTRY—II.

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Development of Organic Chemistry in the Last Fifty Years

THE science of organic chemistry developed, as we have seen, very slowly until consistent ideas as to the mode of combination of the elements, and consequently as to the structure of compounds, were established; but since then its growth has been by leaps and bounds. To-day the organic chemist has prepared, described, and ascertained the constitution of compounds numbering 150,000 or more; amongst these, in addition to a large number which had previously been isolated from natural products, are a vast number never known until built up in the laboratory. Indeed as soon as he established the structural principles upon which organic compounds are built up, he became an architect and designer of chemical structures, using as units the radicles or groups, and proceeded in his laboratory to learn how to build up such structures. And so it is now possible to synthesize in the laboratory a relatively complex substance such as uric acid from its elements; or, starting from benzene or napthalene, the chemist may finish with a dye-stuff, a regular skyscraper of a compound whose structural formula fills half a page and whose systematic name requires several lines of type in more than one font.

In this connection it may be remarked that the so-called coal-tar or aniline dyes bear about the same relation to coal-tar or aniline as a steel battleship does to a heap of iron ore, the latter being merely the raw material from which the former is fashioned. Moreover, an artificial or synthetic substance is no imitation or substitute, but is the real thing and indeed is often purer and better than the natural product; synthetic indigo is real indigo, a synthetic ruby is a real ruby, the only difference being that one is produced by what we are pleased to call natural processes, whereas in the other the process is controlled so as to yield a pure product.

The successful synthesis of a substance is usually not possible until its structure has been established, a matter which may require long-continued laborious effort and analysis; even then it may be realized very slowly, for one must learn how to make his units combine to form the structure desired. Successful synthesis in the laboratory does not imply that this synthesis will directly be carried out on a large scale;

the development of an economically feasible scheme of operations requires a time measured in years rather than in months—even in war-time, when considerations of financial economy are secondary and when more effective co-operation can be secured, the interval between preparation by the gram and production by the ton is a matter of many months. Indeed in some cases—e. g., sugar and rubber—there is no immediate prospect of synthetic production on any large scale, because the material can be built up in the growing plant—the sugar cane or the rubber tree—at a cost comparable with that of the basic raw material required in its artificial production.

The story of even a single achievement in synthesis would be so long and would involve so many technical details and explanations that it cannot be given here; we shall have to limit ourselves to a mention of some of the outstanding examples, premising that these achievements became possible only because of knowledge slowly accumulated by the efforts of many men possessed by a curiosity with respect to the inwardness of things.

Aniline, discovered first in 1840 as a decomposition product of indigo, was found in coal-tar by Hofmann in 1843; in 1845, after his discovery of benzene in coal-tar, Hofmann could make aniline in large quantities from benzene. In 1856 Perkin, a student of Hofmann, while oxidizing some crude aniline, obtained a dye; this was mauve, the first of the aniline dyes, the starting-point of an industry which has since grown to enormous proportions. In 1868 alizarin, hitherto prepared from madder root, was synthesized, and, within a few years, was being made on a large scale, to the complete displacement of the natural product. Indigo was prepared first in 1870, made from accessible coal-tar derivatives in 1880, but it was not until 1890 that the process was discovered which ultimately proved successful commercially; about 1902 the synthetic indigo came on the world-market, and by 1914 Germany was selling over a million pounds a month at about fifteen cents a pound, as compared with a price four times as great ten years earlier. This list of materials made from coal-tar derivatives could be extended indefinitely to include a whole host of compounds, many of which were not known at all until built up by the chemist, used as dyes or drugs, antiseptics or anaesthetics, perfumes or flavors, and now indeed considered indispensable.

About a hundred years ago, Biot observed that a ray of light polarized in one plane has that plane twisted in passing through certain organic substances; and that the direction and extent of this rotation of the plane of polarization is different for different substances. In 1848, Pasteur—who later elucidated the whole question of fermentation and became the father of the science of bacteriology—observed that ordinary tartaric acid rotates the polarized ray strongly to the right, but that certain tartars yielded an acid called racemic acid, iden-

tical with tartaric acid in every respect except that it was optically inactive. On further investigation he discovered that this racemic acid is a mixture of two kinds of tartaric acid in equal quantities and having equal but opposite effects on polarized light; and that the crystals of the dextro form and of the laevo form differ only as the right hand differs from the left or an object from its mirror-image. Pasteur also found that any organic optically active substance will yield two forms of crystal, left-handed and right-handed, and concluded that in such pairs of substances the arrangement of atoms must in one case be the inverse of the other. There the interpretation of the matter rested until 1874, when van't Hoff and Le Bel correlated the observations by the discovery that the molecule of an optically active organic compound contains at least one so-called asymmetric carbon atom—that is, a carbon atom linked to four different groups—showing that optical activity vanishes as soon as the carbon atom ceases to be asymmetric. This type of isomerism cannot be readily visualized through structural formulae written in one plane; but van't Hoff made it clear by picturing the carbon atom as a regular tetrahedron with linkages extending outwards from the four apices, and by using solid models to represent the compounds. On this basis it is apparent that a molecular structure comprising an asymmetric carbon atom may be either right- or left-handed and that there will be two such stereoisomers for each asymmetric carbon atom present; and the facts have been found to be in complete accordance with these deductions.

The phenomenon of optical activity and its interpretation on a stereo-chemical basis have proved of great usefulness, for it has been to the chemist a very powerful tool in ascertaining the constitution of many organic compounds. Particularly is this so in the case of the sugars which have the general empirical formula $C_6H_{12}O_6$. When Emil Fischer started systematic work upon the sugars, in 1883, practically nothing was known as to their constitution; in 1908, when his collected papers on sugar were published, the complex relationships had been resolved. Fischer had succeeded in determining the structural formula, and in synthesizing, each of the important sugars; he had prepared many of the possible stereoisomers, thereby confirming the usefulness of van't Hoff's theory, and had, indeed, systematized the whole matter. This is only one of his great achievements; for he had simultaneously established the constitution of many compounds of the so-called purin group, a group which includes substances such as caffeine and uric acid. His work on sugars brought in its train the necessity for examining further the nature and properties of substances which bring about the process of fermentation; from this it is but a short step to the proteins, a class of substances more directly connected with life processes than any other. And in this field likewise, which at the outset presented unparalleled difficulties, Fischer progressed a long

way; he was able to break down the complex substances into simpler amino-acids and other nitrogenous compounds, to ascertain the structure of these decomposition products, and by bringing about recombination of these units to prepare synthetic peptides which approximate to the natural products.

The measure of Fischer's achievement in this matter is brought out by a quotation from a short history of chemistry published as recently as 1899:[12]

> Not only the simple formic and acetic acids, but complex vegetable acids, such as tartaric, citric, salicylic, gallic, cinnamic; not marsh gas and ethylic alcohol only, but phenols, indigo, alizarin, sugars, and even alkaloids identical with those extracted from the tissues of plants, are now producible by purely chemical processes in the laboratory. It might appear that such triumphs would justify anticipations of still greater advances, by which it might become possible to penetrate into the citadel of life itself. Nevertheless the warning that a limit, though distant yet, is certainly set in this direction to the powers of man, appears to be as justifiable now, and even as necessary, as in the days when all these definite organic compounds were supposed to be producible only through the agency of a "vital force." Never yet has any compound approaching the character and composition of albumen or any proteid been formed by artificial methods, and it is at least improbable that it ever will be without the assistance of living organisms.

This illustrates again the danger of prophecies as to the limitation of man's powers; for the limitations set are continually being transcended by the genius, and he would be rash who would now set a limit to what may be learned from biochemical investigations, in view of the extraordinary progress made within the present century; but to discuss this fascinating subject is beyond the scope of this sketch of the development of the principles of chemistry.

General and Inorganic Chemistry Since 1860

Compared with the enormous growth of organic chemistry, that of inorganic chemistry was for a long time insignificant. It remained for many years largely in the hands of the so-called practical man, who has been defined as the man who practices the errors of his grandfather; and contented itself largely with descriptions of substances rather than with their interrelations and structure. As one instance among many, it may be mentioned that there has been no real technical improvement in the Chamber Process of making sulphuric acid—which is the key substance, made by the millions of tons yearly, in all chemical manufacture—since Gay-Lussac invented his absorption tower nearly one hundred years ago; nor does this mean that there is no room for improvement, but merely that it was not *sought properly*. Indeed as late as 1900, many chemists considered that but little more, and that *little* not of the first importance, remained to be done in inorganic chemistry; the truth being the exact opposite—that we had then barely

[12] W. T. Tilden, "A Short History of the Progress of Scientific Chemistry," p. 154.

scratched the surface of this enormous field. It had not been adequately recognized that chemistry had been dealing in the main with the behavior of a rather restricted range of substances over a narrow range of temperature (say, from somewhat below the freezing point up to 400°) and, practically, at a single pressure—with a mere slice of the whole field, in fact—and that these conditions are quite arbitrary when we consider the whole subject-matter of chemistry.

Nor is the development of inorganic chemistry of subsidiary importance, from any point of view. If judged with respect solely to the monetary value of its products it would be far ahead of organic chemistry, as will be obvious if we recall that it is concerned with the production of all our metals, of building materials such as brick, cement, glass, and with the manufacture of all kinds of articles in every-day use. One reason for its comparative neglect for so many years is that inorganic chemistry is in a sense the more difficult in that, whereas organic compounds usually stay put and behave regularly—one might say that organic radicles are conservative and conventional—the behavior of many inorganic compounds is more complex, somewhat analogous to that of Dr. Jekyll and Mr. Hyde; another is that the great successes of organic chemistry attracted a majority of the workers. But the main reason is that the proper theories for the interpretation of the phenomena had not been available, consequently proper tools and adequate methods of investigation had not been developed.

The fundamental idea which was lacking is the conception of chemical equilibrium, the importance of which was not really grasped until about thirty years ago and is not yet adequately apprehended by many chemists. The first contribution to this question we need notice dates from 1865, when Guldberg and Waage published the so-called law of mass-action. This paper may be said to inaugurate the quantitative study of chemical equilibrium, though progress for many years was quite slow. Indeed at that time the conception of equilibrium was very recent; of the few cases then known, the majority were certain gases which had been observed to expand with rise in temperature in an apparently anomalous manner as compared to the so-called permanent gases; this anomaly was accounted for on the basis that a progressive dissociation of the gas, e. g. ammonium chloride (NH_4Cl) into simpler molecules of ammonia (NH_3) and hydrochloric acid (HCl), takes place on heating and that the constituents recombine on subsequent cooling. Hundreds of instances are now known, all of which are in quantitative accord with the law of mass-action.

According to this law, the extent of chemical action within a homogeneous gaseous system is determined by the "active mass",—or better, the effective concentration—of each species of molecule taking part in the reaction; this implies that an apparently stationary condition, a

state of equilibrium, is finally reached, at which point the tendency of the reaction to go forward is just counterbalanced by the tendency of the reverse reaction. This may be made more objective by an actual example. By the equation

$$\underset{\text{carbon monoxide}}{CO} + \underset{\text{steam}}{H_2O} \rightleftarrows \underset{\text{hydrogen}}{H_2} + \underset{\text{carbon dioxide}}{CO_2}$$

we symbolize the fact that under appropriate conditions in any mixture of the gases CO and H_2O some proportion of the gases H_2 and CO_2 will be formed, and conversely, in any mixture of H_2 and CO_2 some proportion of CO and H_2O will be formed; and the law of mass-action states that the concentrations of the several gases will always adjust themselves so that ultimately

$$\frac{[H_2]}{[CO]}\frac{[CO_2]}{[H_2O]} = K$$

where the symbols $[H_2]$, etc., denote the concentrations of the several reacting species, and K is a constant, the equilibrium constant, the value of which depends upon the temperature but not upon the original amounts of any of the substances. From this it is obvious that, if we know the value of K corresponding to any temperature, we are in position to predict exactly what will happen in any mixture in which this reaction may take place, and consequently to select the conditions under which the maximum yield of any one of the substances may be expected. The usefulness of this is so apparent as to require no comment.

The law of mass-action is but a special case of the general question of equilibrium treated so comprehensively by Willard Gibbs, at that time Professor of Mathematical Physics at Yale, on the general basis of the laws of thermodynamics. These two laws now underlie so much of the reasoning upon which advances in chemistry and physics have been based that we must go back a little to consider them.

The doctrine that heat is an imponderable became finally untenable about 1860, when the work of Mayer in Germany and of Joule in England had finally convinced everybody that heat is a form of energy, and that heat and work are quantitatively interchangeable. This leads directly to the First Law of Thermodynamics, the doctrine of the conservation of energy, that energy is indestructible and uncreatable, that energy, though apparently disappearing, is simultaneously reappearing in another form. The second law in its briefest form is that a thermodynamic perpetual motion is impossible; perhaps I can best convey an idea of it by means of the picturesque analogies of a recent writer:[13]

> There is one law that regulates all animate and inanimate things. It is formulated in various ways, for instance: Running down hill is easy. In Latin it reads, *facilis descensus Averni.* Herbert Spencer calls it the dissolution of definite coherent heterogeneity into indefinite incoherent homo-

[13]Slosson, Creative Chemistry, page 145.

geneity. Mother Goose expresses it in the fable of Humpty Dumpty, and the business man extracts the moral as, "You can't unscramble an egg." The theologian calls it the dogma of natural depravity. The physicist calls it the second law of thermodynamics. Clausius formulates it as "The entropy of the world tends toward a maximum." It is easier to smash up than to build up. Children find that this is true of their toys; the Bolsheviki have found that it is true of a civilization.

These two laws, which had been established largely by the work of Mayer, Joule, Clausius and William Thomson (later Lord Kelvin), have only been confirmed by all subsequent work; and they are now considered as fundamental as any laws in physical science. The great advance in applying them generally to chemical processes is due to Gibbs, who in 1876 and 1878 printed in the Transactions of the Connecticut Academy the two parts of his epoch-making paper "On the Equilibrium of Heterogeneous Substances." Gibbs was, however, so far in advance of his time and his paper was moreover so inaccessible, that the importance of his work was not recognized for ten years, when it was proclaimed by Roozeboom and began to be used as a guide—almost entirely by Hollanders and Germans—in the interpretation of chemical phenomena. It is hardly too much to say that the very large number of subsequent advances in this field are merely applications and variations of Gibbs' fundamental considerations; that his paper mapped out the lines of advance in a new field of chemical science comparable in importance to that uncovered by Lavoisier. The conception of equilibrium in chemical processes constitutes the central idea of what is commonly called physical chemistry, which however would be better termed theoretical or general chemistry since it deals with the general principles of the science.

To many Gibbs' name is familiar only as the formulator of the phase rule, a general principle, derived from his thermodynamic discussion of chemical equilibrium, which enables one to sort chemical systems tending to equilibrium into categories, and to state qualitatively what behavior may be expected in each type of system. The phase rule has been of indispensable service in the elucidation of problems as apparently diverse as the constitution of alloys (another large field in which we have done little more than scratch the surface hitherto); the origin of salt-deposits in the earth; the separation of potash or other valuable salts from the waters of saline lakes; the relation between different crystal forms of the same chemical substance, as exemplified in many minerals and in the so-called allotropic modifications of the elements themselves (e. g. diamond and graphite; phosphorus, white and red, etc.). Indeed the service which these doctrines with respect to chemical equilibrium have rendered is but a fraction of what they will render to chemical science, and hence to the people at large.

For a long time there had been investigations looking towards a

relation between physical properties and chemical constitution. An early instance is the work of Dulong and Petit, who discovered that equal amounts of heat are required to raise equally the temperature of solid and liquid elements, provided quantities are taken proportional to the atomic weights; and this was frequently used as a criterion in fixing upon the proper atomic weight. This is an instance of the necessity of comparing quantities which are really comparable chemically, instead of equal weights; that regularities which otherwise would remain hidden will be apparent when an equal number of chemical units —molecules—are considered. Hence it is obvious that few such regularities would be observed so long as there was confusion with respect to atoms and molecules; but since 1860 there has been continuous progress in this direction, though until very recently chemists had in their comparisons often made insufficient use of chemical units, as compared with the arbitrary unit of weight, the gram. As examples of this type of relationship we may mention: the heat capacities (specific heats) of gases; the molecular volume, the heat-change accompanying combustion, formation, or melting, particularly as applied to homologous series of organic compounds; the relation between constitution and color and other optical properties, etc.

Along with this went naturally the question of the properties of a substance as affected by mixture with another, of solutions in particular. The fact that the boiling-point of a solution is higher than that of the solvent itself had long been known, and measurements of the rise in boiling point caused by equal weights of dissolved material had been made; but it was not until 1884 that Ostwald pointed out that this rise is approximately the same, for any one solvent, when computed for equal numbers of molecules dissolved in the same amount of the solvent. The measurements had been mainly of solutions of a salt in water; but in 1886 Raoult extended the observations to other substances and stated what is now known as Raoult's law, which may be considered as the fundamental law formulating the dependence of the general properties of a perfect solution upon its composition; namely, the lowering of the vapor pressure of the solvent is proportional to the number of dissolved molecules per unit of solvent, or as now frequently phrased, the partial pressure of a component of a solution is proportional to its molar fraction, the molar fraction being defined as the ratio of the number of molecules of that component to the total number of molecules present. Soon thereafter van't Hoff gave the thermodynamic relationships between lowering of vapor pressure and raising of boiling-point, lowering of freezing-point, and osmotic pressure; by means of which any one of these may be deduced from another provided that certain constants characteristic of the solvent are known. It was then possible, from such measurements, to calculate the mole-

cular weight of the substance in solution; when this was done, many of the results were anomalous—in particular, the apparent molecular weight of a salt in solution in water was little more than half what one would expect from its formula.

Now it had long been known that certain classes of substances dissolved in water yield a solution which is a good conductor of electricity, and that aqueous solutions of other substances are poor conductors; the former class, called electrolytes by Faraday, comprises salts, acids and bases (alkalies), whereas the typical non-electrolyte is an organic substance such as sugar. And it was precisely these electrolytes which exhibited the anomalous molecular weight. To account for this anomaly Arrhenius propounded the theory of electrolytic dissociation, the basic idea of which is that the electrolytes, when dissolved in water, dissociate into two or more constituent particles, that these constituents are the ions, or carriers of electricity through the solution, and that each ion affects the general properties of the solution just as if it were an independent molecule. This theory is another landmark in the field of chemistry, for it has served to correlate and systematize a very large number of apparently diverse facts.

It would lead too far to go into the consequences and applications of the theory of ionization; how it enables us to choose the optimum conditions under which to carry out many analytical operations; how it leads to the view that acidity is determined by the actual concentration of hydrogen-ion (H^+), and basicity (alkalinity) by hydroxyl-ion (OH^-), etc. Its usefulness and importance in aiding us towards a real knowledge of aqueous solutions—a knowledge so essential to progress in many lines—is so great as to require no emphasis. And yet the theory is not completely satisfactory, there being still some outstanding anomalies, particularly in connection with the so-called strong electrolytes as typified by ordinary salts; but there is hope that these discrepancies will disappear with the growth of knowledge of electrochemistry.

The fundamental law of electrochemistry was discovered by Faraday prior to 1840, namely: that one unit of electricity transports one chemical equivalent of an ion, irrespective of voltage, temperature, concentration or other conditions. Later, it was established that these ions move independently of one another, and with characteristic velocities, facts which, with others, were satisfactorily coordinated by the theory of ionization; which in turn led to greatly improved control of practical electrochemical processes, such as electroplating. Again, it had long been known that an electromotive force is set up whenever there is a difference of any kind at two electrodes immersed in an electrolyte, and when two similar electrodes are placed in different solutions, or in solutions of the same substance at different concentrations. The next

step in advance was taken by Nernst, in 1889, who, from thermodynamical reasoning confirmed by direct experiment, deduced the relation between the electro-motive force and the ratio of effective concentration of the active ion in one solution to that in the other. Measurement of electromotive force, therefore, under appropriate conditions, yields independent information as to the effective concentration, or activity, of the ions. Nor is this the only application of this principle to the development of chemistry; for it also affords a measure of chemical affinity.

One of the characteristic phenomena accompanying a chemical change is an evolution or absorption of heat; in other words, the amount of heat contained by the reacting system changes with the chemical change. The measurement of this heat change, which may range from a large negative quantity through zero to a large positive quantity, is the province of thermo-chemistry. Our knowledge of these heats of reaction is largely due to Thomsen and to Berthelot, each of whom started from the supposition that the heat effect is a direct measure of relative affinity; and it was with this end in view that they carried out the very laborious work involved in these determinations. It is now clear that this supposition is erroneous, that the maximum work producible by a reaction, or its free energy, is a truer measure of affinity, the heat effect being an important factor in this maximum work or free energy. The systematic determination of the free energy of reactions, one of the most potent methods being the electrical method outlined above, is an outstanding task of modern chemistry, of consequence to the progress of the science as well as to industrial progress.

Graham, the discoverer in 1829 of the law relating the rate of diffusion of a gas to its density, later made experiments on the rate of diffusion of dissolved substances through animal membranes; this work led him to divide substances into two categories—the rapidly moving crystalloids, typified by salt, and the slow moving colloids, typified by gum arabic or gelatine. For a long time this distinction persisted, colloids being regarded as somewhat mysterious, rather messy, substances; and it was apparently considered a good explanation of some ill-understood phenomenon to attribute it, if possible, to a colloid. This whole matter received little systematic attention for forty years and only after 1900 did it become evident that we should not speak of a colloid as a distinct class of substances, but may speak only of the colloidal state. The characteristic phenomenon is the dispersion of one substance in another, the system being therefore heterogeneous; and the properties of the colloidal system depend upon the kind of particle, and upon their fineness,—in short, upon the nature and extent of the surface of separation of the two phases. In an outline on the present

scale one cannot go further into colloid chemistry, except to say that nearly everything remains to be done and that increased knowledge of the subject is fundamental to progress along many lines in biology and medicine, and is also of inestimable importance to all manner of industries, ranging from tanning to pottery.

Closely connected with this, since they also are surface effects, are the phenomena of adsorption and of catalysis, both known in more or less isolated instances for a long time, and both very ill understood. Their importance has been demonstrated recently, the former in connection with the provision of a satisfactory gas-mask, the latter as a means of making certain products—for instance, edible fats out of inedible oils,—in the fixation of atmospheric nitrogen, etc. And there is no question that both phenomena will be made use of increasingly, and that this increase will be accelerated as soon as we begin to understand the principles underlying these phenomena, a matter upon which we are still in the dark. Indeed, even as it is, extension of the use of catalytic methods is proceeding so rapidly that predictions are being made that we are entering upon what might be called a catalytic age in so far as the making of many chemical products is concerned.

As we have already noted, practically all chemical work, until very recently, had been carried out within a temperature range extending only from 0° up to 400° and at pressures ranging from atmospheric down to, say, 0.01 atmosphere. But the recent extension of these ranges has had so many practical consequences as to require some mention. This extension, though it hardly involves any important new chemical principle, has in a sense been equivalent to one, in that it has forced chemists to consider the subject more broadly and to remember that "ordinary conditions" are quite arbitrary in reference to the subject as a whole. To illustrate, the chemistry at the 1000° horizon, though subject to the same general principles, has to deal with only a small fraction of the compounds familiar to us at the 25° horizon, and is incomparably simpler; at the 2000° horizon it would be still simpler, and at still higher temperatures—as in many of the stars—the elements, at that temperature all gaseous, in place of being combined with one another, would probably be in part themselves dissociating.

Before 1845 Faraday had succeeded in liquefying, by cooling and compressing, many of the gases then known; but a few of the most common gases—viz., nitrogen, oxygen, hydrogen, carbon monoxide, nitric oxide, methane—resisted all his efforts, wherefore they were often alluded to as the "permanent gases." The clue was given in 1861 by Andrews, who showed that there is for each gas a critical temperature above which it cannot be liquefied by any pressure whatever;[14] and the reason for lack of success with the permanent gases was that the

lowest temperature employed had been above the critical point of those gases. With appreciation of this point and with improvements of technique, resulting in part from theory and in part from practice, success was finally achieved in all cases; all known gases have therefore now been liquefied, and there is only a difference in degree of "permanence" between hydrogen which condenses to liquid at 30° absolute and water vapor (steam) which condenses at 373° absolute. The main victories in conquering this region are given in the following table:

LIQUEFACTION OF THE "PERMANENT" GASES

Substance	Date when liquid first obtained	Observer	Liquid Critical Temperature C.	abs.	Boiling Temperature C.	abs.	Freez'g Temp. C.	abs.
Oxygen	1883	Wroblewski	—118°	155	—181°	92	—235	38
Nitrogen	1883	Wroblewski	—146	127	—195	78	—215	58
Hydrogen	1898	Dewar	—243	30	—252	21	—248	17
Helium	1908	Onnes	—268	5	—269	4		2.5

To this may be added that liquid air was first obtained by Wroblewski in 1885, was available for research purposes in 1891, and since 1895, with the development of the commercial machine for producing it, has become an industry; it is now indispensable to several lines of work—for instance, wherever very low pressures are required. Incidentally, too, its development resulted in the invention of the vacuum-jacketed, or Dewar, tube which is now a necessary tool in all work at low temperatures and a convenience to the community generally.

With the command of low temperatures, it is now possible to make accurate measurement, e. g. of specific heats, at temperatures not so far removed from the absolute zero. And there is reason to believe that this type of work is going to furnish very valuable information on some moot questions; for instance, on the entropy of substances at the lowest temperatures and on the applicability of the Nernst heat theorem, called by some the third law of thermodynamics—questions which bear a very intimate relation to the problem of the nature of chemical affinity.

Apart from mainly qualitative work, such as that of Moissan with his arc-furnace on the carbides, little accurate high-temperature work was done until about 1900. In the meantime methods of control and measurement have been developed to such an extent that many types of measurement may be made just as accurately at 1000° as at 100°. This has enabled many equilibria, both homogeneous (usually in gas systems) and heterogeneous (that is, essentially solubilities), to be determined carefully over a wide range of temperature. Such knowledge is essential for many purposes, both practical and theoretical—from the nature of combustion to the constitution of alloys and the mode of formation of minerals and rocks. Very recently high tem-

[14]Though, as we now know, it may be solidified by application of sufficient pressure at temperatures higher than the critical end-point of the liquid.

peratures have been coupled with minimal pressures in experimental work on electron emission and related topics; but this is at the moment usually considered a part of the domain of physics, which has not yet received adequate attention from a chemical point of view. In the field of high pressures, as in that of high temperatures, recent technical progress has made it possible to follow many types of changes with as high accuracy at a pressure of 10,000 atmospheres (i. e. 150,000 pounds to the square inch) as at 10 atmospheres. This is bringing to light phenomena hitherto unsuspected; thus, when the whole range is considered, it appears to be the rule, rather than the exception, that a substance when solidified exists in more than one crystalline form, each stable within a definite range of temperature and pressure. As an instance of this, there are in addition to ordinary ice, at least four other forms of crystalline water, stable at high pressure; and under increasing high pressure the freezing temperature of water steadily rises until at, for instance, a pressure of 20,000 atm. it freezes about 73° (centigrade) higher than its ordinary freezing point.

The phenomena observed at high and low temperatures and at high and low pressures all illustrate the fact that chemistry should not be looked upon as a collection of isolated things which can be manipulated in a sort of magical way, but is to be thought of as, in a sense, almost a continuum all parts of which are subject to definite laws, still incompletely elucidated; the relative behavior of all substances being controlled by these laws in the same sense as the relative motions of the heavenly bodies are controlled by the law of gravitation.

In this brief sketch of the development of chemical science, many things must remain unmentioned. Yet it must not be supposed that these things are intrinsically unimportant; indeed an explanation of some puzzling phenomenon may arise out of work in another field, apparently entirely unrelated, each advance in knowledge of any field being that much wrested from the domain of ignorance, and reacting in favor of advances at other points of the line. In particular it has not been practicable to mention the several branches of applied chemistry, for instance, the study of the substances and reactions involved in life-processes, with its remarkable advance within the last few years, which would require a chapter to itself; or even analytical chemistry, an essential branch of the subject, which develops with each development of principle, and is to be regarded as including all methods of analysis and not merely the semi-traditional methods applied to a somewhat restricted group of salts of certain metallic bases. The growth of the whole subject-matter may perhaps be gauged from the fact that the 1920 volume of Chemical Abstracts, which gives merely brief abstracts of papers of interest to chemists published within the year, contains more than 4,000 pages, and that the index to this volume alone

will cover more than 600 pages closely printed in double column. From this it is obvious that, even though a large proportion of these papers contain little of real value, one cannot keep abreast of advances in the whole subject but can only hope to have a general knowledge of principles and to acquire a special knowledge of some restricted field.

These principles of chemical science are of its essence and constitute its philosophy; only with development of this philosophy will it be possible to progress in the correlation and systematization of the multitudinous facts of chemistry. The progress of this philosophy, which indeed demands the services of the physicist as much as those of the chemist, is obliterating the line of demarcation between these two sciences. Initially physics dealt mainly with changes which affect matter independently of its composition, whereas chemistry was concerned mainly with the change of composition; but the physicist and chemist came to meet on common ground for the reason that the quantitative measures of most of the so-called physical properties are intimately connected with the constitution of the substance. And it may be said that the recent very significant advances—dating, say from the discovery of the X-rays—concern the chemist just as much as the physicist, and that each of them should be conversant with the general mode of thought of the other. Indeed the several sciences have in the past been too far apart from one another, and we should now seek increased co-operation, for it is precisely in the boundary regions between them that the most valuable advances in the immediate future will be made.

THE BIOLOGY OF DEATH—VI. EXPERIMENTAL STUDIES ON THE DURATION OF LIFE[1]

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1. Inheritance of Duration of Life in Drosophila

IN the last paper there was presented indubitable proof that inheritance is a major factor in determining the duration of life in man. The evidence, while entirely convincing and indeed in the writer's opinion critically conclusive, must be, in the nature of the case, statistical in its nature. Experimental inquiries into the duration of human life are obviously impossible. Public opinion frowns upon them in the first place, and even if this difficulty were removed man would furnish poor material for the experimental study of this particular problem because he lives too long. It is always important, however, as a general principle, and particularly so in the present instance, to check one's statistical conclusions by independent experimental evidence. This can be successfully done, when one's problem is longevity, only by choosing an animal whose life-span relative to that of man is a short one, and in general the briefer it is the better suited will the animal be for the purpose.

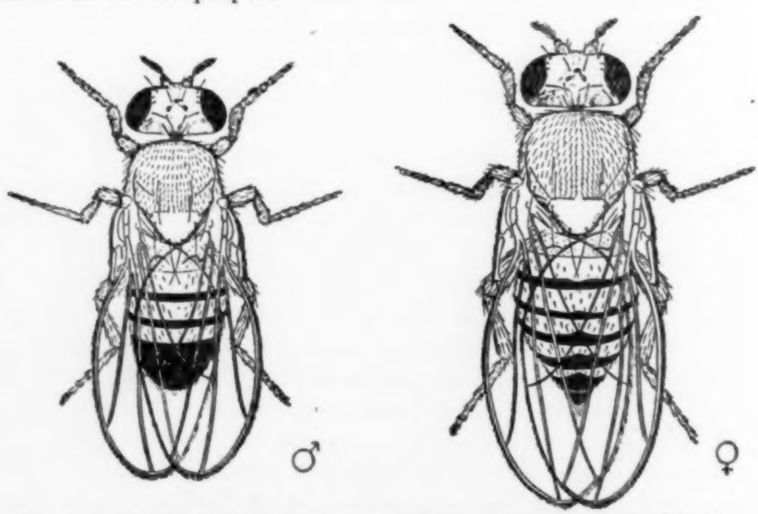

FIG. 1. MALE AND FEMALE FRUIT FLY (*Drosophila melanogaster*). (From Morgan)

[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 33.

An organism which rather completely fulfils the requirements of the case, not only in respect of the shortness of the life span, but also in other ways, such as ease of handling, feeding, housing, etc., is the common "fruit" or "vinegar" fly, *Drosophila melanogaster*. This creature, which every one has seen hovering about bananas and other fruit in fruit shops, has lately attained great fame and respectability as a laboratory animal, as a result of the brilliant and extended investigations of Morgan and his students upon it, in an analysis of the mechanism of heredity. *Drosophila* is a small fly, perhaps one fourth as large as the common house fly. It has striking red eyes, a brownish body, and wings of length and form varying in different strains. It lives normally on the surface of decaying fruit of all sorts, but because of a more or less well marked preference for banana it is sometimes called the "banana" fly. While it lives on decaying fruit surfaces its food is mainly not the fruit itself, but the yeast which is always growing in such places.

The life cycle of the fly is as follows: The egg laid by the female on some fairly dry spot on the food develops in about 1 day into a larva. This larva or maggot squirms about and feeds in the rich medium in which it finds itself for about 3 to 4 days and then forms a pupa. From the pupa the winged imago or adult form emerges in about 4 or 5 days. The female generally begins to lay eggs within the first 24 hours after she is hatched. So then we have about 8 to 10 days as the minimum time duration of a generation. The whole cycle from egg to egg, at ordinary room temperature, falls within this 10-day period with striking accuracy and precision.

The duration of life of the adult varies in an orderly manner from less than 1 day to over 90 days. The span of life of *Drosophila* quantitatively parallels in an extraordinary way that of man, with only the difference that life's duration is measured with different yardsticks in the two cases. Man's yardstick is one *year* long, while *Drosophila's* is one *day* long. A fly 90 days old is just as decrepit and senile, for a fly, as a man 90 years old is in human society.

This parallelism in the duration of life of *Drosophila* and man is well shown in Fig. 2, which represents a life table for adult flies of both sexes. The survivorship, or l_x figures, are the ones plotted. The curves deal only with flies in the adult or imago stage, after the completion of the larval and pupal periods. The curve is based upon 3,216 female and 2,620 male flies, large enough numbers to give reliable and smooth results. We note at once that in general the curve has the same form as the corresponding l_x curve from human mortality tables. The most striking difference is in the absence from the fly curves of the heavy infant mortality which characterizes the human curve. There is no specially sharp drop in the curve at the beginning of the life cycle,

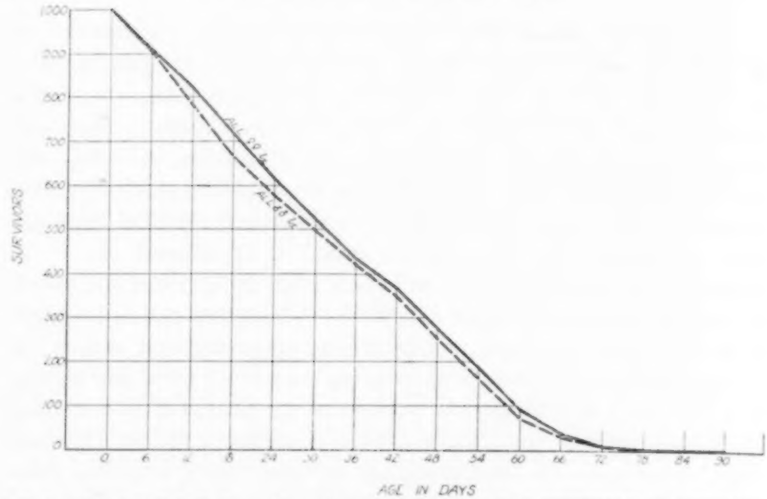

FIG. 2. LIFE LINES FOR *Drosophila melanogaster*, SHOWING THE SURVIVORS AT DIFFERENT AGES OUT OF 1000 BORN AT THE SAME TIME

such as has been seen in the l_x curve for man in an earlier paper in this series. This might at first be thought to be accounted for by the fact that the curve begins after the infantile life of the fly, but it must be remembered that the human l_x line begins at birth, and no account is taken of the mortality *in utero*. Really the larval and pupal stages of the fly correspond rather to the foetal life of a human being than to the infant life, so that one may fairly take the curves as covering comparable portions of the life span in the two cases and reach the conclusion that there is not in the fly an especially heavy incidence of mortality in the infant period of life, as there is in man. The explanation of this fact is, without doubt, that the fly when it emerges from the pupal stage is completely able to take care of itself. The baby is, on the contrary, in an almost totally helpless condition at the same relative age.

It is further evident that at practically all ages in *Drosophila* the number of survivors at any given age is higher among the females than among the males. This, it will be recalled, is exactly the state of the case in human mortality. The speed of the descent of the *Drosophila* curve slows off in old age, just as happens in the human life curve. The rate of descent of the curve in early middle life is somewhat more rapid with the flies than in the case of human beings, but as will presently appear there are some strains of flies which give curves almost identical in this respect with the human mortality curves. In the life curves of Figure 2, all different degrees of inherited or constitutional variation in longevity are included together. More accurate pictures of the true state of affairs will appear when we come, as we presently shall, to deal with groups of individuals more homogeneous in respect of their hereditary constitutions.

Having now demonstrated that the incidence of mortality is in general similar in the fly *Drosophila* to what it is in man, with a suitable change of unit of measure, we may proceed to examine some of the evidence regarding the inheritance of duration of life in this organism. The first step in such an examination is to determine what degree of natural variation of an hereditary sort exists in a general fly population in respect of this characteristic. In order to do this it is necessary to isolate individual pairs, male and female, breed them together and see whether, between the groups of offspring so obtained, there are genetic differences in respect of duration of life which persist through an indefinite number of generations. This approaches closely to the process called by geneticists the testing of pure lines. In such a process the purpose is to reduce to a minimum the *genetic* diversity which can possibly be exhibited in the material. In a case like the present, the whole amount of genetic variation in respect of duration of life which can appear in the offspring of a single pair of parents is only that which can arise by virtue of its prior existence in the parents themselves individually, and from the combination of the germinal variation existing in the two parents one with another. We may call the offspring, through successive generations, of a single pair of parents a line of descent. If, when kept under identical environmental conditions such lines exhibit widely different average durations of life, and if these differences reappear with constancy in successive generations, it may be justly concluded that the basis of these differences is hereditary in nature, since by hypothesis the environment of all the lines is kept the same. In consequence of the environmental equality whatever differences do appear must be inherently genetic.

The manner in which these experiments are performed may be of interest. An experiment starts by placing two flies, brother and sister, selected from a stock bottle, together in a half-pint milk bottle. At the bottom of the bottle is a solidified, jelly-like mixture of agar-agar and boiled and pulped banana. On this is sown as food some dry yeast. A bit of folded filter paper in the bottle furnishes the larvae opportunity to pupate on a dry surface. About ten days after the pair of flies have been placed in this bottle fully developed offspring in the imago stage begin to emerge. The day before these offspring flies are due to appear, the original parent pair of flies are removed to another bottle precisely like the first, and the female is allowed to lay another batch of eggs over a period of about nine days. In the original bottle there will be offspring flies emerging each day, having developed from the eggs laid by the mother on each of the successive days during which she was in the bottle. Each morning the offspring flies which have emerged during the preceding twenty-four hours are transferred to a small bottle. This has, just as the larger one, food material at the

bottom and like the larger one is closed with a cotton stopper. All of the offspring flies in one of these small bottles are obviously of the same age, because they were born at the same time, using this term "born" to denote emergence from the pupal stage as imagines. Each following day these small bottles are inspected. Whenever a dead fly is found it is removed and a record made in proper form of the fact that its death occurred, and its age and sex are noted. Finally, when all the flies in a given small bottle have died that bottle is discarded, as the record of the duration of life of each individual is then complete. All the bottles are kept in electric incubators at a constant temperature of 25° C., the small bottles being packed for convenience in wire baskets. All have the same food material, both in quality and quantity, so that the environmental conditions surrounding these flies during their life may be regarded as substantially constant and uniform for all.

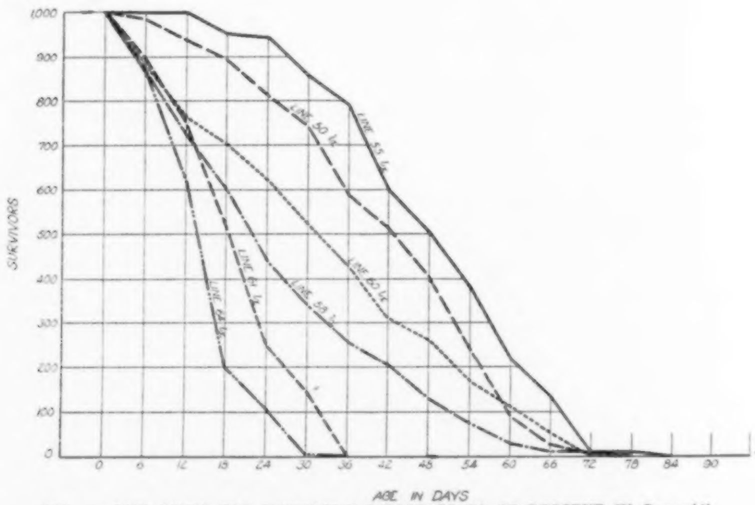

FIG. 3. LIFE LINES FOR DIFFERENT INBRED LINES OF DESCENT IN *Drosophila*

Fgure 3 shows the survival frequency, or l_x line of a life table, for six different lines of *Drosophila*, which have been bred in my laboratory. Each line represents the survival distribution of the offspring of a single brother and sister pair mated together. In forming a line a brother and sister are taken as the initial start because by so doing the amount of genetic variation present in the line at the beginning is reduced to the lowest possible minimum. It should be said that in all of the curves in Figure 3 both male and female offspring are lumped together. This is justifiable for illustrative purposes because of the small difference in the expectation of life at any age between the sexes. The line of descent No. 55 figured at the top of the diagram gives an l_x line extraordinarily like that for man, with the exception of

the omission of the sharp drop due to infantile mortality at the beginning of the curve. The extreme duration of life in this line was 81 days, reached by a female fly. The l_x line drops off very slowly until age 36 days. From that time on the descent is more rapid until 72 days of age are reached when it slows up again. Lines 50, 60, and 58 show l_x curves all descending more rapidly in the early part of the life cycle than that for line 55, although the maximum degree of longevity attained is about the same in all of the four first curves. The general shape of the l_x curves changes however, as is clearly seen if we contrast line 55 with line 58. The former is concave to the base through nearly the whole of its course, whereas the l_x curve for line 58 is convex to the base practically throughout its course. While, as is clear from the diagram, the maximum longevity attained is about the same for all of these upper four lines, it is equally obvious that the mean duration of life exhibited by the lines falls off as we go down the diagram. The same process, which is in operation between lines 55 and 58, is continued in an even more marked degree in lines 61 and 64. Here not only is the descent more rapid in the early part of the l_x curve, but the maximum degree of longevity attained is much smaller, amounting to about half of that attained in the other four lines. Both lines 61 and 64 tend to show in general a curve convex to the base, especially in the latter half of their course.

Since each of these lines of descent continues to show through successive generations, for an indefinite time, the same types of mortality curves and approximately the same average durations of life, it may safely be concluded that there are well marked hereditary differences in different strains of the same species of *Drosophila* in respect of duration of life. Passing from the top to the bottom of the diagram the average expectation of life is reduced by about two-thirds in these representative curves. For purposes of experimentation, each one of these lines of descent becomes comparable to a chemical reagent. They have a definitely fixed standard duration of life, each peculiar to its own line and determined by the hereditary constitution of the individual in respect of this character. We may, with entire justification, speak of the flies of line 64 as hereditarily and permanently short-lived, and those of line 55 as hereditarily long-lived.

Having established so much, the next step in the analysis of the mode of inheritance of this character is obviously to perform a Mendelian experiment by crossing an hereditarily short-lived line with a hereditarily long-lived line, and follow through in the progeny of successive generations the duration of life. If the character follows the ordinary course of Mendelian inheritance, we should expect to get in the second offspring generation a segregation of different types of flies in respect of their duration of life.

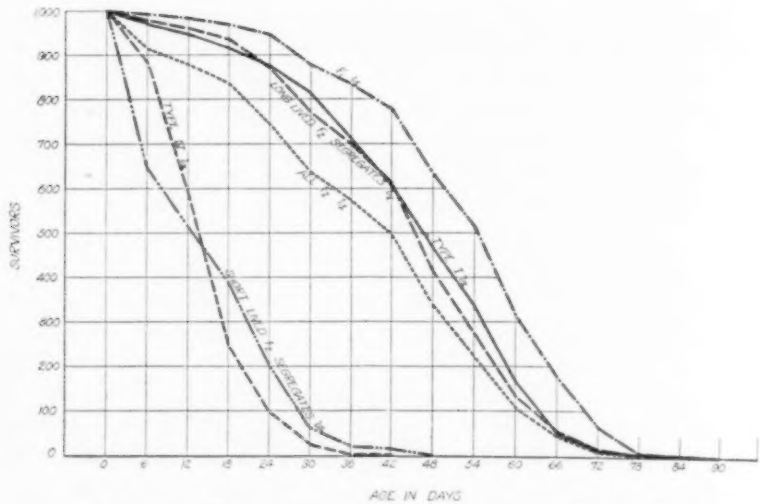

FIG. 4. LIFE LINES SHOWING THE RESULT OF MENDELIAN EXPERIMENTS ON THE DURATION OF LIFE IN *Drosophila*. Explanation in text

Figure 4 shows the result of such Mendelian experiment performed on a large scale. In the second line from the top of the diagram, labelled "Type I l_x," we see the mortality curve for an hereditarily long-lived pure strain of individuals. At the bottom of the diagram the "Type IV l_x" line gives the mortality curve for one of our hereditarily short-lived strains. Individuals of Type I and Type IV were mated together. The result in the first offspring hybrid generation is shown by the line at the top of the diagram marked "F_1 l_x." The F_1 denotes that this is the mortality curve of the ***first filial generation*** from the cross. It is at once obvious that these first generation hybrids have a greater expectation of life at practically all ages than do either of the parent strains mated together to produce the hybrids. This result is exactly comparable to that which has for some time been known to occur in plants, from the researches particularly of Professor E. M. East of Harvard University with maize. East and his students have worked out very thoroughly the cause of this increased vigor of the first hybrid generation and show that it is directly due to the mingling of different germ plasms.

The average duration of life of the Type I original parent stock is 44.2 $\pm$ .4 days. The average duration of life of the short-lived Type IV flies is 14.1 $\pm$ .2 days, or only about one third as great as that of the other stock. The average duration of life of the first hybrid generation shown in the F_1 l_x line is 51.5 $\pm$ .5 days. So that there is an increase in average duration of life in the first hybrid generation, over that of the long-lived parent, of approximately 7 days. In estimating the significance of this, one should remember that a day in the life of a

fly corresponds, as has already been pointed out, almost exactly to a year in the life of a man.

When individuals of the first hybrid generation are mated together to get the second, or F_2 hybrid generation we get a group of flies which, *if taken all together*, give the mortality curve shown in the line at about the middle of the diagram, labelled "All F_2 l_x." It, however, tells us little about the mode of inheritance of the character if we consider all the individuals of the second hybrid generation together, because really there are several kinds of flies present in this second hybrid generation. There are sharply separated groups of long-lived flies and of short-lived flies. These have been lumped together to give the "All F_2 l_x" line. If we consider separately the long-lived second generation group and the short-lived second generation group we get the results shown in the two lines labelled "Long-lived F_2 Segregates l_x," and "Short-lived F_2 Segregates l_x." It will be noted that the long-lived F_2 segregates have a mortality curve which almost exactly coincides with that of the original parent Type I stock. In other words, in the second generation after the cross of the long-lived and short-lived types a group of animals appears having almost identically the same form of mortality curve as that of one of the original parents in the cross. The mean duration of life of this long-lived second generation group is $43.3 \pm .4$ days, while that of the original long-lived stock was $44.2 \pm .4$ days. The short-lived F_2 segregates shown at the bottom of the diagram give a mortality curve essentially like that of the original short-lived parent strain. The two curves wind in and about each other, the F_2 flies showing a more rapid descent in the first half of the curve and a slower descent in the latter half. In general, however, the two are very clearly of the same form. The average duration of life of these short-lived second generation segregates is $14.6 \pm .6$ days. This, it will be recalled, is almost identically the same average duration of life as the original parent Type IV gave, which was $14.1 \pm .2$ days.

It may occur to one to wonder how it is possible to pick out the long-lived and short-lived segregates in the second generation. This is done by virtue of the correlation of the duration of life of these flies with certain external bodily characters, particularly the form of the wings, so that this arrangement of the material can be made with perfect ease and certainty.

These results show in a clear manner that duration of life, in *Drosophila* at least, is inherited essentially in accordance with Mendelian laws, thus fitting in with a wide range of other physical characters of the animal which have been thoroughly studied, particularly by Morgan and his students. Such results as these just shown constitute the best kind of proof of the essential point which we are getting at—namely, the fact that duration of life is a normally inherited character.

I do not wish at this time to go into any discussion of the details of the Mendelian mechanism for this character, in the first place, because it is too complicated and technical a matter for discussion here,[2] and in the second place, because the investigations are far from being completed yet. I wish here and now merely to present the demonstration of the broad general fact that duration of life is inherited in a normal Mendelian manner in these fly populations. The first evidence that this was the case came from some work of Dr. R. R. Hyde with *Drosophila* some years ago. The numbers involved in his experiment, however, were much smaller than those of the present experiments, and the preliminary demonstration of the existence of pure strains relative to duration of life in *Drosophila* was not undertaken by him. Hyde's results and those here presented are entirely in accord.

With the evidence which has now been presented regarding the inheritance of life in man and in *Drosophila* we may let that phase of the subject rest. The evidence is conclusive of the broad fact, beyond any question I think, coming as it does from such widely different types of life, and arrived at by such totally different methods as the statistical, on the one hand, and the experimental, on the other. We may safely conclude that the primary agent concerned in the winding up of the vital clock, and by the winding determining primarily and fundamentally how long it shall run, is heredity. The best insurance of longevity is beyond question a careful selection of one's parents and grandparents.

2. Bacteria and Duration of Life in Drosophila

But clocks may be stopped in other ways than by running down. It will be worth while to consider with some care a considerable mass of most interesting, and in some respects even startling, experimental data, regarding various ways in which longevity may be influenced by external agents. Since we have just been considering *Drosophila* it may be well to consider the experimental evidence regarding that form first. It is an obviously well-known fact that bacteria are responsible in all higher organisms for much organ breakdown and consequent death. An infection of some particular organ or organ system occurs, and the disturbance of the balance of the whole so brought about finally results in death. But is it not possible that we overrate the importance of bacterial invasion in determining, in general and in the broadest sense, the average duration of life? May it not be that when an organ system breaks down under stress of bacterial toxins, that it is in part at least, perhaps primarily, because for internal organic reasons the resistance of that organ system to bacterial invasion has normally

[2] Full technical details and all the numerical data regarding these and other *Drosophila* experiments referred to in this and other papers in the series, will shortly be published elsewhere.

and naturally reached such a low point that its defenses are no longer adequate? All higher animals live constantly in an environment far from sterile. Our mouths and throats harbor pneumonia germs much of the time, but we do not all or always have pneumonia. Again it may fairly be estimated that of all persons who attain the age of 35, probably at least 95 per cent. have at some time or other been infected with the tubercle bacillus, yet only about one in ten breaks down with active tuberculosis.

What plainly is needed in order to arrive at a just estimate of the relative influence of bacteria and their toxins in determining the average duration of life is an experimental inquiry into the effect of a bacteria-free, sterile mode of life. Metchnikoff has sturdily advocated the view that death in general is a result of bacterial intoxication. Now a bacteria free existence is not possible for man. But it is possible for certain insects, as was first demonstrated by Bogdanow, and later confirmed by Delcourt and Guyenot. If one carefully washes either the egg or the pupa of *Drosophila* for 10 minutes in a strong antiseptic solution, say 85 per cent. alcohol, he will kill any germs which may be upon the surface. If the bacteria-free egg or pupa is then put into a sterile receptacle, containing only sterile food material and a pure culture of yeast, development will occur and presently an adult imago will emerge. Adult flies raised in this way are sterile. They have no bacteria inside or out. Normal healthy protoplasm is normally sterile, so what is inside the fly is bound to be sterile on that account, and by the use of the antiseptic solution what bacteria were on the outside have been killed.

The problem now is, how long on the average do such sterile specimens of *Drosophila* live in comparison with the ordinary fly, which is throughout its adult life as much beset by bacteria relatively as is man himself, it being premised that in both cases an abundance of proper food is furnished and that in general the environmental conditions other than bacterial are made the same for the two sets? Fortunately, there are some data to throw light upon this question from the experiments of Loeb and his associate Northrop on the duration of life in this form, taken in connection with experiments in the writer's laboratory.

Loeb and Northrop show that a sample of 70 flies, of the *Drosophila* with which they worked, which were proved by the most careful and critical of tests to have remained entirely free of bacterial contamination throughout their lives, exhibited, when grown at a constant temperature of 25° C. *an average duration of life of 28.5 days.* In our experiments 2620 male flies, of all strains of *Drosophila* in our cultures taken together, thus giving a fair random sample of genetically the whole *Drosophila* population, gave an average duration of life at the same constant temperature of 25° C. of 31.3 ± .3 days, and 3216

females under the same temperature lived an average of $33.0 \pm .2$ days. These were all non-sterile flies, subject to all the bacterial contamination incident to their normal laboratory environment, which we have seen to be a decaying germ-laden mass of banana pulp and agar. It is thought to be fairer to compare a sample of a general population with the Loeb and Northrop figures rather than a pure strain because probably their *Drosophila* material was far from homozygous in respect of the genes for duration of life.

The detailed comparisons are shown in Table 1.

TABLE 1

Average duration of life of Drosophila in the imago stage at 25° C.

Experimental group	Mean duration of life in days	Number of flies
Sterile (Loeb and Northrop)	28.5	70
Non-sterile, males, all genetic lines (Pearl)	31.3	2620
Non-sterile, females, " " " "	33.0	3216
Non-sterile, both sexes, " " " "	32.2	5836
Difference in favor of non-sterile	3.7	....
Probable error of difference about	± 1.0	....

We reach the conclusion that bacteria-free *Drosophila* live no longer on the average, and indeed perhaps even a little less long, under otherwise the same constant environmental conditions, than do normal non-sterile—indeed germ-laden—flies. This result is of great interest and significance. It emphasizes in a direct experimental manner that in a *broad biological sense* bacteria play but an essentially accidental role in determining length of the span of life in comparison with the influence of heredity. There is every reason to believe that if the same sort of experiment were possible with man as material, somewhat the same sort of result in broad terms would appear.

3. Poverty and Duration of Life

But we must take care lest we seem to convey the impression that no sort of environmental influence can affect the average duration of life. Such a conclusion would be manifestly absurd. Common sense tells us that environmental conditions in general can, and under some circumstances, do exert a marked influence upon expectation of life. A recent study of great interest and suggestiveness, if perhaps some lack of critical soundness, by the eminent Swiss statistician, Hersch, well illustrates this. Hersch became interested in the relation of poverty to mortality. He gathered data from the 20 arrondissements of the City of Paris in respect of the following points, among others:

a. Percentage of families not paying a personal property tax.
b. Death rate per 1000 from all causes.
c. Still births per 1000 living births.

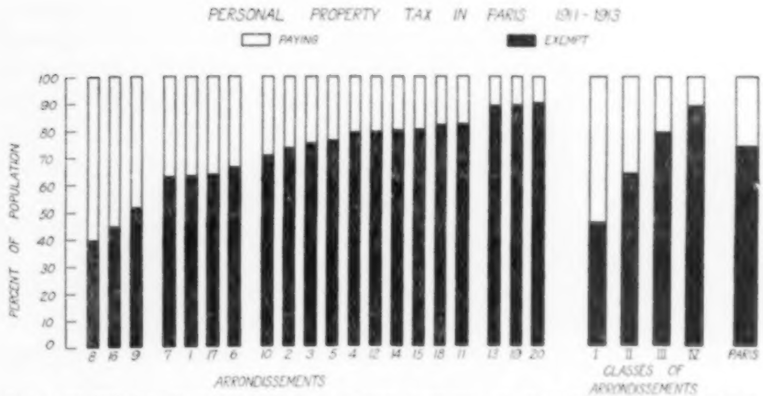

FIG. 5. DISTRIBUTION OF POVERTY IN PARIS (1911-13) AS INDICATED BY EXEMPTION FROM PERSONAL PROPERTY TAX. (After Hersch)

Figure 5 shows in the black the percentage of families too poor to have any personal property tax assessed, first for each arrondissement separately, then at the right in broader bars for the four groups of arrondissements separated by wider spaces in the detailed diagram, and finally for Paris as a whole. It will be seen that the poverty of the population, measured by the personal property yardstick, is least at the lefthand end of the diagram, where the smallest percentages of families are exempted from the tax, and greatest at the right hand end, where scarcely any of the population is well enough to do to pay this tax.

FIG. 6. DEATH RATES IN PARIS (1911-13) FROM ALL CAUSES. (After Hersch)

Figure 6 shows the death rates from all causes for the same arrondissements and the same groups. It is at once apparent that the black bars in this group run in a parallel manner to what they did in the preceding one. The poorest districts have the highest death rates, the richest districts the lowest death rates, and districts intermediate in respect of poverty are also intermediate in respect of mortality. On the face of the evidence there would seem to be here complete proof of

the overwhelmingly important influence upon duration of life of degree of poverty, which is perhaps the most potent single environmental factor affecting civilized man to-day. But, alas, pitfalls proverbially lurk in statistics. Before we can accept this so alluring result and go along with our author to his final somewhat stupendous conclusion that if there were no poverty the death rate from certain important causes, as for example tuberculosis, would forthwith become *zero*, we must exercise a little inquisitive caution. What evidence is there that the inhabitants of the districts showing a high poverty rate are not *biologically* as well as economically differentiated from the inhabitants of districts with a low poverty rate? And again what is the evidence that it is not such biological differentiation rather than the economic which determines the death rate differences in the two cases? Unfortunately, our author gives us no whit of evidence on these obviously so important points. He merely assumes, because of the facts shown, that if some omnipotent spook were to transpose all the inhabitants of the Menilmontant arrondissement to the Elysee arrondissement, and *vice versa* for example, and were to permit each group to annex the worldly goods of the dispossessed group, then the death rates would be forthwith interchanged. There is no real evidence that any such result would follow at all. Probably from what we know from more critical studies than this of the relation of social and economic conditions to mortality, each group would exhibit under the new circumstances a death rate not far different from what it had under the old conditions. One can not shake in the slightest degree from its solidly grounded foundation the critically determined fact of the paramount importance of the hereditary factor in determining rates of mortality, which have been summarized in this and the preceding paper, by any such evidence as that of Hersch.

TABLE 2

Still births in Paris (1911-13) by classes of arrondissements (Hersch)

Classes of Arrondissements	Absolute figures: Still births	Absolute figures: Living births	Still births per 100 living births
I	1,004	12,313	8.2
II	1,390	19,998	7.0
III	7,279	82,821	8.8
IV	3,024	30,853	9.8
Paris	12,679	145,985	8.7

This, indeed, he himself finds to be the fact when he considers the extremely sensitive index of hereditary biological constitution furnished by the still-birth rate. Table 2 gives the data. We see at once that there is no such striking increase in the total mortality as we pass from

the richest class of districts, as was shown in the death rate from all causes. Instead there is practically no change, certainly none of significance, as we pass from one class of districts to another. The rate is 8.2 per 100 living births in the richest class and 9.8 in the poorest.

4. Experiments on Temperature and Duration of Life

Altogether it is plain that we need another kind of evidence than the simple unanalyzed parallelism which Hersch demonstrates between poverty and the general death rate if we are to get any deep understanding of the influence of environmental circumstances upon the duration of life or the general death rate. We shall do well to turn again to the experimental method. About a dozen years ago Loeb,

starting from the idea that chemical conditions in the organisms are one of the main variables in this case, raised the question whether there was a definite coefficient for the duration of life and whether this temperature coefficient was of the order of magnitude of that of a chemical reaction. The first experiments were made on the unfertilized and fertilized eggs of the sea urchin and could only be carried out at the upper temperature limits of the organism, since at ordinary temperatures this organism lives for years. In the upper temperature region the temperature coefficient for the duration of life was very high, probably on account of the fact that at this upper zone of temperature death is determined by a change of the nature of a coagulation or some other destructive process. Moore, at the suggestion of Loeb, investigated the temperature coefficient for the duration of life for the hydranth of a tubularian at the upper temperature limit and found that it was of the same order of magnitude as that previously found for the sea urchin egg. In order to prove that there is a temperature coefficient for the duration of life throughout the whole scale of temperatures at which an organism can live experiments were required on a form whose duration of life was short enough to measure the duration of life even at the lowest temperature.

A suitable organism was found in *Drosophila*. This was grown under aseptic conditions, as already described. The general results are shown in Table 3.

TABLE 3

Effect of temperature on duration of life of Drosophila.
(After Loeb and Northrop)

Temperature	Duration (in days) of			
	Larval stage	Pupal stage	Life of imago	Total duration of life from egg to death
°C				
10	57	Pupae die	120.5	177.5 + x
15	17.8	13.7	92.4	123.9
20	7.77	6.33	40.2	54.3
25	5.82	4.23	28.5	38.5
27.5	(4.15)	3.20	....	....
30	4.12	3.43	13.6	21.15

From this table it is seen that at the lowest temperature the duration of life is longest, and the highest temperature shortest. Cold slows up the business of living for the fly. Heat hastens it. One gathers, from the account which Loeb and Northrop give of the work, that at low temperature the flies are sluggish and inactive in all three developmental stages and perhaps live a long time because they live slowly. At high temperatures, on the other hand, the fly is very active and lives its life through quickly at the "pace that kills." These results are exactly comparable to the effect of a regular increase of temperature upon a chemical reaction. Indeed, Loeb and Northrop consider that their results prove that

> With a supply of proper and adequate food the duration of the larval stage is an unequivocal function of the temperature at which the larvae are raised, and the temperature coefficient is of the order of magnitude of that of a chemical reaction, i. e., about 2 or more for a difference of 10° C. It increases at the lower and is less at the higher temperatures. The duration of the pupal stage of the fly is also an unequivocal function of the temperature and the temperature coefficient is for each temperature practically identical with that for the larval stage. The duration of life of the imago is, with proper food, also an unequivocal function of the temperature and the temperature coefficient for the duration of life is within the normal temperature limits approximately identical with that for the duration of life of the larva and pupa.

How are these results to be reconciled with the previous finding that heredity is a primary factor in the determination of duration of life of *Drosophila?* We have here, on first impression at least, an excellent example of what one always encounters in critical genetic investigations: the complementary relations of heredity and environment. In our experiments a general mixed population of *Drosophila* kept under *constant environment* was shown to be separable by selection into a number of very diverse strains in respect of duration of life. In Loeb and Northrop's experiments a general mixed population of *Drosophila*, but of presumably *constant genetic constitution*, at least approximately such, throughout the experiment, was shown to exhibit changes of duration of life with changing environments. It is the old familiar deadlock. Heredity constant plus changing environment equals diversity. Environment constant plus varying hereditary constitution also equals diversity.

Can we penetrate no farther than this into the matter? I think in the present case we can. In Loeb and Northrop's experiments, temperature and duration of life were not the only two things that varied. The different temperature groups also differed from each other—*because* of the temperature differences to be sure but not less really—in respect of general metabolic *activity*, expressed in muscular movement and every other way. In the genetic experiments metabolic

activity was substantially equal in all the hereditarily different lines. The idea suggests itself, both on *a priori* grounds and also upon the basis of certain experimental data presently to be in part reviewed, that possibly duration of life may be an implicit function of only the two variables

a. Genetic constitution
b. Rate of metabolic activity.

The functional relations of metabolic activity with temperature, food, light and other environmental factors are all well known. For present purposes we do not need to go into the question of their exact form. The essential point is that all these environmental factors stand in definite functional relations to rate of metabolic activity, and do not so stand in relation to genetic constitution. Genetic constitution is not a function of the environment, but is for any individual a constant, and only varies between individuals.

This may be thought merely to be an involved way of saying what one knows *a priori;* namely, that duration of life, in general and in particular, depends only upon heredity and environment. So in one sense it is. But the essential point I would make here is that the *manner in which the environmental forces (of sub-lethal intensity, of course) chiefly act in determining duration of life appears to be by changing the rate of metabolism of the individual.* Furthermore one would suggest, on this view, that what heredity does in relation to duration of life is chiefly *to determine, within fairly narrow limits, the total energy output which the individual can exhibit in its life time.* This limitation is directly brought about presumably through two general factors; viz, (a) the kind or quality of material of which this particular vital machine is built, and (b) the manner in which the parts are put together or assembled. Both of these factors are, of course, expressions of the extent and character of the processes of organic evolution which have given rise to this particular species about which we may be talking in a particular instance.

There is some direct experimental evidence, small in amount to be sure, but exact and pertinent, to the effect that the duration of life of an animal stands in inverse relation to the total amount of its metabolic activity, or put in other words, to the work, in the sense of theoretical mechanics, that it *as a machine* does during its life. Slonaker kept 4 albino rats in cages like the old fashioned revolving squirrel cages, with a properly calibrated odometer attached to the axle, so that the total amount of running which they did in their whole lives could be recorded. The results were those shown in Table 4.

TABLE 4

Relation of longevity to muscular activity in rats (Slonaker)

Total number of miles run during life

Age in months at death	Rat No. 1 Miles	No. 4 Miles	No. 2 Miles	No. 3 Miles
25	1265			
26		1391		
32			2098	
34				5447

It will be perceived that the amount of exercise taken by these rats was astonishingly large. For a rat to run 5,447 miles in the course of its life is indeed a remarkable performance. Now these 4 rats attained an average age at death of 29.5 months. But three control rats confined in stationary cages so that they could only move about to a limited degree, but otherwise under conditions, including temperature, identical with those in the revolving cages, attained an average age at death of 40.3 months. All were stated to have died of "old age." From this experiment it appears clearly that the greater the total work done, or total energy output, the shorter the duration of life, and *vice versa.* Or, put in another way, if the total activity per unit of time is increased by some means other than increasing temperature, the same results appear as if the increased activity is caused by increased temperature. It appears, in short, to be the activity *per se*, and not the temperature *per se* that is of real significance. There is other evidence, for which space lacks here, pointing in the same direction.

If we may be permitted to make a suggestion regarding the interpretation of Loeb and Northrop's results in conjunction with our own on *Drosophila*, it would be to this effect. Any given genetically pure strain of *Drosophila* is made up of individual machines, constructed to turn out before breaking down a definite limited amount of energy in the form of work, mechanical, chemical, and other. This definitely limited total energy output is predetermined by the hereditary constitution of the individual which fixes the kind of physicochemical machine that that individual is. But the *rate* per unit of time of the energy output may be influenced between wide limits by environmental circumstances in general and temperature in particular, since increased temperature increases rate of metabolic chemical changes in about the same ratio, as demonstrated by a wealth of work on temperature coefficients, as it increases other chemical changes. But if the rate of energy output per unit of time is changed, the total time taken for the total output of a predetermined amount of energy as work must change in inverse proportion to the change of rate. So we should expect just precisely the results on duration of life that Loeb and Northrop got, and so far from these results being in contradiction to ours upon

heredity they may be looked upon as a necessary consequence of them. Loeb and Northrop's final conclusion is: "The observations on the temperature coefficient for the duration of life suggest that this duration is determined by the production of a substance leading to old age and natural death or by the destruction of a substance or substances which normally prevent old age and natural death." The view which I have here suggested completely incorporates this view within itself, if we suppose that the total amount of hypothetical "substance or substances which normally prevent old age and natural death" was essentially determined by heredity.

5. Gonads and Duration of Life

There is another and quite different line of experimental work on the duration of life which may be touched upon briefly. The daily press has lately had a great deal to say about rejuvenation accomplished by means of various surgical procedures undertaken upon the primary sex organs, particularly in the male. This newspaper notoriety has especially centered about the work of Voronoff and Steinach. The only experiments which at the present time probably deserve serious consideration are those of Steinach. He has worked chiefly with white rats. His theory is that by causing through appropriate operative procedure an extensive regeneration, in a senile animal about to die, of certain glandular elements of the testis, senility and natural death will for a time be postponed because of the internal secretion poured into the blood by the regenerated "puberty glands" as he calls them. The operation which he finds to be most effective is to ligate firmly the efferent duct of the testis, through which the sperm normally pass, close up to the testis itself and before the coiled portion of the duct is reached. The result of this, according to Steinach's account, is to bring about in highly senile animals a great enlargement of all the sex organs, a return of sexual activity previously lost through old age, and a general loss of senile bodily characteristics and a resumption of the conditions of full adult vigor in those respects.

Space is lacking to go into the many details of Steinach's work, much of which is indeed chiefly of interest only to the technical biologist, and from a wholly different standpoint than the present one. I should, however, like to present one example from his experiments. As control a rat was taken in the last degree senile. He was 26 months old when the experiment began. He was obviously emaciated, had lost much of his hair, particularly on the back and hind quarters. He was weak, inactive and drowsy, as indicated by the fact that his eyes were closed, and were, one infers from Steinach, kept so much of the time.

A litter brother of this animal had the efferent ducts of the testes ligated. This animal, we are told, was at the time of the operation, in

so much worse condition of senility than his brother above described that it was not thought worth while even to photograph him. His condition was considered hopeless. To the surprise of the operator, however, he came back, slowly but surely after the operation, and after three and a half months presented a perfect picture of lusty young rathood. He was in full vigor of every sort, including sexual. He outlived his brother by 8 months, and himself lived 10 months after the operation, at which time he was, according to Steinach, practically moribund. This represents a presumptive lengthening of his expected span of life by roughly a quarter to a third. *It is to be remembered, however, that Slonaker's rats to which nothing was done lived to an average age of 40 months.*

The presumption that Steinach's experiments have really brought about a statistically significant lengthening of life is large, and the basis of ascertained fact small. After a careful examination of Steinach's brilliant contribution, one is compelled to take the view that however interesting the results may be from the standpoint of functional rejuvenation in the sexual sphere, the case is not proven that any really significant lengthening of the life span has occurred. In order to prove such a lengthening we must first of all have abundant and accurate quantitative data as to the normal variation of normal rats in respect of duration of life, and then show, having regard to the probable errors involved, that the mean duration of life after the operation has been significantly lengthened. This Steinach does not do. His paper is singularly bare of statistical data. We may well await adequate quantitative evidence before attempting any general interpretation of his results.

6. The Pituitary Gland and Duration of Life

Robertson has been engaged for a number of years past on an extensive series of experiments regarding the effect of various agents upon the growth of white mice. The experiments have been conducted with great care and attention to the proper husbandry of the animals. In consequence the results have a high degree of trustworthiness. In the course of these studies he found that the anterior lobe of the pituitary body, a small gland at the base of the brain, normally secretes into the blood stream minute amounts of an active substance which has a marked effect upon the normal rate of growth. By chemical means Robertson was able to extract this active substance from the gland in a fairly pure state and gave to it the name *tethelin*. In later experiments the effect of tethelin given by the mouth with the food was tried in a variety of ways.

In a recent paper Robertson and Ray have studied the effect of this material upon the duration of life of the white mouse with the results shown in Table 5.

TABLE 5

Effect of tethelin on duration of life in days of white mice.
(Robertson and Ray)

Class of animals	MALES: Average duration of life	MALES: Dev. from normal	MALES: Dev. / P. E.	MALES: Chance dev. was accidental	FEMALES: Average duration of life	FEMALES: Dev. from normal	FEMALES: Dev. / P. E.	FEMALES: Chance dev. was accidental	Both sexes together: Chance dev. was accidental
Normal	767	----	----	------	719	----	----	-----	------
Tethelin	866	+ 99	3.00	1:22.25	800	+ 81	2.25	1:6.75	1:150.2

From this table it is apparent that the administration of tethelin with the food from birth to death prolonged life to a degree which in the case of the males may be regarded as probably significant statistically. In the case of the females where the ratio of the deviation to its probable error (Dev. / P. E.) falls to 2.25 the case is very doubtful. The procedure by which the chance of 1:150.2 that results in both sexes together were accidental, was obtained is of doubtful validity. Putting males and females together from the original table I find the following results.

TABLE 6

Duration of life of white mice, both sexes taken together
(From data of Robertson and Ray)

Age Group	No. of deaths of normals (Both Sexes)	No. of deaths of tethelin fed (Both Sexes)
200-299	3	..
300-399	2	..
400-499	2	1
500-599	9	3
600-699	7	9
700-799	15	..
800-899	10	10
900-999	10	6
1000-1099	6	9
1100-1199	..	1
	64	39

Tethelin fed: Mean age at death $= 839 \pm 20$
Normal fed: Mean " " " $= 743 \pm 17$
Difference $= 96 \pm 26$

$$\frac{\text{Difference}}{\text{P. E.}_{\text{Diff.}}} = 3.7$$

One concludes from these figures that tethelin can be regarded as having lengthened the span of life to a degree which is just significant statistically. One would expect from the variation of random sampling alone to get as divergent results as these about $1\frac{1}{4}$ times in every 100 trials with samples of 64 and 39, respectively.

In any event it is apparent that, making out the best case possible, the differences in average duration of life produced by administration of tethelin are of a wholly different and smaller order than those which

have been shown in the earlier portion of the paper to exist between pure strains of *Drosophila* which are based upon hereditary differences.

Putting together all the results which have been reviewed in this and the preceding paper, it appears to be clearly and firmly established that inheritance is the factor of prime importance in determining the normal, natural duration of life. In comparison with this factor the influence of environmental forces (of sub-lethal immediate intensity of course) appears in general to be less marked.

ADAPTATIONS AMONG INSECTS OF FIELD AND FOREST

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IT is well known that there are more kinds or species of insects in the world than of all other animals. The number has been placed by various authorities at from one to ten million and careful estimates indicate that we have in the State of New York some 20,000 kinds or species of insects, all differing from each other by more or less striking characters and in the great majority of species, there are also recognizable variations between the eggs, the maggots, larvae or caterpillars, and the pupae or chrysalids, not to mention striking differences between the life habits of these varied forms.

Summarizing, we have among insects an immense complex exhibiting innumerable variations, some large, many minor and practically all significant. It is proposed to examine briefly some of the more striking of these differences in the hopes of reaching a better understanding of the insect problem as a whole.

It happens that some years ago a list of all the insects known to occur in the State of New Jersey was prepared and a careful analysis of this shows that nearly one-half of all the insects therein recorded are plant feeders, about one-sixth are predaceous, living mostly upon other insects, another one-sixth are scavengers and live mostly upon decaying organic matter and one-eighth are parasitic upon other animals, mostly insects.

Among plant feeders we find one or more species living at the expense of practically every growing plant. It may be that some plants, such as oak and apple trees, are particularly adapted to insect requirements and support a very large number of species. It may also be observed that practically all parts of the plant are liable to attack, including the roots, the wood or bark of the trunk, of the larger limbs, of the smaller limbs, the buds, the developing leaves and flowers in the buds, the fully developed flowers, the expanded leaves, the immature fruit and the mature fruit; and broadly speaking there are insects which confine themselves exclusively or nearly so to the parts designated. This restriction is so marked that we have a large series of small beetles known as seed weevils, because they live almost entirely in seeds of various plants. There is one entire family, the members of which

bore almost exclusively in the bark and outer sap wood of trees and because of this habit they are commonly known as bark beetles. Many of the plant feeders, it might be added, are considered injurious because of the extensive losses they cause in cultivated crops; but it should be remembered that comparatively few of the many plant feeders are numerous enough to be of economic importance.

The predaceous insects, approximately one-sixth of all the species, habitually prey upon smaller animals, mostly insects, and are indirectly beneficial because they destroy intentionally or otherwise many destructive forms. The rapid, active, brightly colored tiger beetles, many of the ground beetles, the ferocious dragon flies, the peculiar aphis lions (the young of the lazy golden-eyed fly), all come in this category together with many others.

The scavenger insects, comprising the burying beetles, many flies, etc., are nearly as numerous as the predatory forms and, like other insects, exhibit marked variations in structure and habits.

The parasites, somewhat less numerous than the two preceding groups, are in many cases indirectly beneficial since they prey upon injurious forms and incidentally hunt their prey under conditions which would frequently seem to promise immunity from attack. Here we find hyperparasitism which may involve three or even four of these pirates working in the same host and each attacking the one ahead, as it were.

Semi-aquatic and even aquatic insects are not protected by the surrounding water from parasites and also borers inhabiting deep galleries in hard wood by no means escape many enemies of this character. Even the caterpillars of the pitch moth, living and moving about readily in pitch and covered with this medium for a large proportion of their existence succumb to the attacks of these vigilant enemies. There is one entire family of small parasites which specialize upon insect eggs, some being so minute that they can develop successfully in the extremely small codling moth egg, which latter has a diameter only about one-half that of the head of an ordinary pin and is furthermore very flat and scale-like.

A general survey of insects as a whole shows all manner of variations from the minute midge approximately one-fiftieth of an inch in length to our largest moths or grass-hoppers with a wing spread of some eight inches. There are endless modifications in form from the oval body of certain beetles or even scale insects to the extremely attenuated forms such as dragon flies and walking sticks. The principal organs of the body, such as the antennae or feelers, the eyes, the legs and the wings are modified in innumerable ways and in some insects have disappeared entirely while in others they have been developed to an extraordinary degree.

We have been taught that insects have heads, wings, and legs and pass through four stages of development, namely, the egg, the larva or the caterpillar, the pupa or chrysalis and the adult; and yet modification has proceeded to such an extent that it is possible to find some insects where both structures and stages have been eliminated or concealed to such an extent that, in a broad sense, there are species or stages with and without such important accessories as heads, wings, legs, mates, eggs, larvae, pupae or chrysalids and adults.

There is also a very great variation in the time required to pass through the various transformations or what is known as the life-cycle, this ranging from approximately 7 days in certain species of plant lice or aphids to 17 years in the case of the periodical cicada, sometimes known, though improperly, as the 17 year locust.

Insects and warm weather are synonymous so to speak and yet snow fleas may be found by the millions on snow in late winter, canker worm moths fly and deposit eggs under equally adverse conditions and at this season a peculiar wingless crane fly as well as the odd Boreus may be found crawling upon the snow. The Arctic regions fairly swarm with mosquitoes which have adapted themselves to the rigors of existence in the far north and issue in clouds in the cool, Arctic spring; nevertheless it is true that most insects abound during warm weather and the midsummer months of the temperate zone and the tropical regions are remarkable for their abundance. Some thrive best under humid conditions and others have adapted themselves to the arid wastes of desert regions. These are simply suggestions regarding climatic diversities endurable by insects.

Turning from the general to special instances, aphids or plant lice illustrate in a striking manner the possibilities of relatively defenseless forms maintaining themselves under adverse conditions. These are all soft bodied insects with indifferent powers of flight and slow movement on foot; nevertheless there are something over 300 species living upon a considerable variety of plants and frequently occurring in enormous numbers. Individually, they are not particularly prolific, they are preyed upon by a considerable series of aggressive parasites and predators; but in spite of these handicaps are able to maintain themselves, because many of them produce a generation within a very short time, some 7 days, and in addition certain species at least periodically migrate to other plants. One migration is from birch to witchhazel and vice versa. This change enables the aphids to escape, for a time at least, from the frequently abundant natural enemies on the infested trees and it also provides the insects with fresh and more acceptable food, since badly infested plants soon become unsuitable for the maintenance of the insects.

The indirect effect of climate is well illustrated among aphids since a rise in temperature in warm weather in the spring is favorable to the development of a number of efficient enemies and consequently such conditions are very likely to result in a speedy control of a plant louse outbreak through natural agencies.

Certain gall making aphids exhibit very striking adaptations. Some species only curl the leaves and through such distortion obtain considerable protection from the elements and presumably also from parasites, while certain of these forms simply establish themselves upon the part of the plant selected and apparently, as a result of the withdrawal of sap due to its feeding, the adjacent plant cells grow up around the insect and eventually inclose it with protective walls, within which the mother plant louse and her young develop in security. There is such a close adaptation between plant and insect in some cases that the aphid is dependent upon finding a given species of plant and being able to establish itself upon a certain developing part, such as a leaf stem, the base of the leaf or the developing shoot.

Biological modifications among plant lice have gone farther than this and we not only find an alternation of food plants with a more or less well defined migration but also, in some species, well marked alternations of series of generations, these series being so different that before the connection was established, they were supposed to belong to entirely different species.

There is a very intimate relation between many insects and the host plant and this is especially close in the case of the oaks and the long series of gall wasps, a large and peculiar group, mostly confined to the oaks, remarkable because of the varied forms of the numerous galls they produce and noteworthy on account of the fact that a considerable series presents a peculiar phenomenon known as alternation of generations. This may be briefly described as a series of unlike alternate generations; in other words parents and children are unlike, while parents and grandchildren are alike. It appears to be a special adaptation due to the fact that one generation frequently develops upon the leaves while the other lives in galls on the twigs or even roots. The adults of one appear in warm, midsummer weather and those of the other issue under the inclement conditions of late fall or early spring.

The long series of plant feeding insects mentioned above show marked specialization in the case of some forms which actually live upon a peculiar fungus cared for and grown by themselves. This may easily be seen in the case of a number of our timber beetles, insects which make deep galleries in the dying wood of trees and utilize the moist conditions there present for the growing of a small fungus known as Ambrosia, which they carry from one tree to another. Certain species of ants, mostly tropical or sub-tropical, cultivate fungi in under-

ground chambers to which they carry portions of leaves cut from trees, using this material as a stratum upon which to grow the fungus.

It should be noted in addition that insects may be found in almost every environment. There are the salt marsh mosquitoes, for example, represented by several species, each with distinct limitations and yet so well adapted to the struggle for existence that one species, at least, may be found breeding in saline pools hundreds of miles from salt marshes. The series of fresh water mosquitoes is larger, exhibits even wider and more varied adaptations than the salt marsh forms and as an extreme case we may mention the peculiar mosquito which lives only, so far as known, in the water of pitcher plants. The silted bottom of shallow pools affords a suitable habitat for small midge larvae, one species of which may be utilized to render milk waste from creameries and cheese factories inoffensive. The maggots of another small fly are important agents in rendering sewage innocuous. The quieter portions of fresh water streams are inhabited by many caddis worms with their peculiar cases, the rapids in such streams support large patches of black fly larvae and between the adjacent stones, there may be found the delicate silken webs of fishing caddis worms. Some aquatic forms have developed to such an extent that they thrive by the millions in the very saline or alkaline lakes of the west and in at least one case the maggots of a small fly develop in pools of petroleum, a product frequently used for the destruction of insect life.

The same varied life conditions obtain among terrestrial forms. Insects are found in almost every conceivable situation, though abundance is dependent to a very great extent upon environment. One of the most remarkable cases of adaptation is found in the buffalo carpet beetle and its close allies. One species has been able to maintain itself for 17 years in an ear of very dry popcorn kept in a practically hermetically sealed fruit jar. More remarkable than this, an investigator has recently demonstrated that grubs of these beetles react to conditions so perfectly that the normal process of molting to permit increase in size and development to maturity may be reversed and in the prolonged absence of suitable nourishment these grubs may actually molt and decrease in size; and not only this but the process may be continued in either direction in individual cases through a series of molts by simply providing or withholding suitable nourishment. This behavior may well be considered an extreme illustration of adaptability so commonly found among insects.

A general knowledge of insects suggests that they have developed in such varied forms and abundance because of an inherent adaptability which has enabled them to exist under a great variety of conditions. This adaptability to environment has been sealed as it were by persistent tendencies toward structural variations, which latter incline to

become more defined whenever a group is somewhat isolated, a condition very likely to follow variations in habit. It is difficult otherwise to explain the almost endless structural modifications found among insects, because it would severely tax human ingenuity to defend them all on the ground of their bestowing a distinct advantage upon the possessor, except possibly, as suggested above, in more firmly establishing specific distinctions and the usual accompanying variations in habits. The relatively long series of similar species of such well segregated units as the cut worms and grass web worms in the Lepidoptera and the June beetles in the Coleoptera, indicate very material advantages in biological adaptations, subsequently confirmed by minor structural variations, since deviations from the normal mean a wider field for the unit as a whole and consequently a greater probability of the type persisting.

Consideration of the general problem compels the admission that insects have gained their present important position in the natural world through an adaptability unequalled in other groups. This has been accomplished by variations favorable to the invasion of unoccupied territory rather than by forcing other organisms into the background, aside from the inevitable limitations, in many cases important, which insects have imposed upon plant life. It is noteworthy that this status should be occupied by a group of comparatively weak, defenseless creatures and the fact that this has been done indicates the possibilities of adaptation. Insects have succeeded where apparently better endowed forms failed, largely because of their greater adaptability.

STUDIES OF THE OCEAN [1]

By H. S. H. THE PRINCE OF MONACO

AFTER exploring for five and twenty years all the levels of the North Atlantic Ocean, from the tropical to the polar regions, chiefly in order to enlarge our knowledge of zoological and physical oceanography, I was commencing more especially such studies as concern physiology, when the German war came and upset the lives of all workers. Eight years were then wasted in the activities of those men who devote themselves primarily to the chief interests of humanity.

Yet such is to-day the power of human thought that in the whole course of the war my oceanographical laboratories never desisted completely from this appointed task; and I was gratified with the sight of two hundred thousand boys of your army visiting the Museum at Monaco while staying on our sunny shore either to heal their wounds or to improve their strength.

When I gave more prominence in my scientific undertakings to physiology, I enjoyed the cooperation of such noted scientists as Charles Richet and Portier, or a few younger men who were thus preparing for their future. Joubin and Bouvier had previously visited with me the awful spaces of the ocean, which almost daily yielded tons of beings unknown to science—abyssal cephalopods or pelagic crustacea. Buchanan and Thoulet, those veterans of the early great labors dealing with the sea, have been for thirty years closely connected with my investigations. And the head of that pleiad, the like of which is hardly likely to be seen again in the laboratory of any ship, was Richard, director of the Oceanographical Museum at Monaco, the faithful fellow-laborer in all my voyages and consequently of all oceanographers, the best versed in our science as a whole.

Owing to Dr. Richard's ingenious ideas and to those of Commandant Bourée, there have been of late years made available large nets with extremely small meshes with which I have explored the intermediate depths of the ocean from the surface down to over 5000 meters. In some instances it has been possible, by means of a special bathometer attached to the net, to ascertain at about what level the capture has taken place.

It was already known that there exists between the great depths and the surface of the seas a fauna consisting of many species and wearing a unique aspect. A sample of that singular world is sometimes

[1] Address before The National Academy of Sciences, April 25, 1921.

THE MONACO OCEANOGRAPHICAL MUSEUM FROM THE GARDENS OF SAINT MARTIN

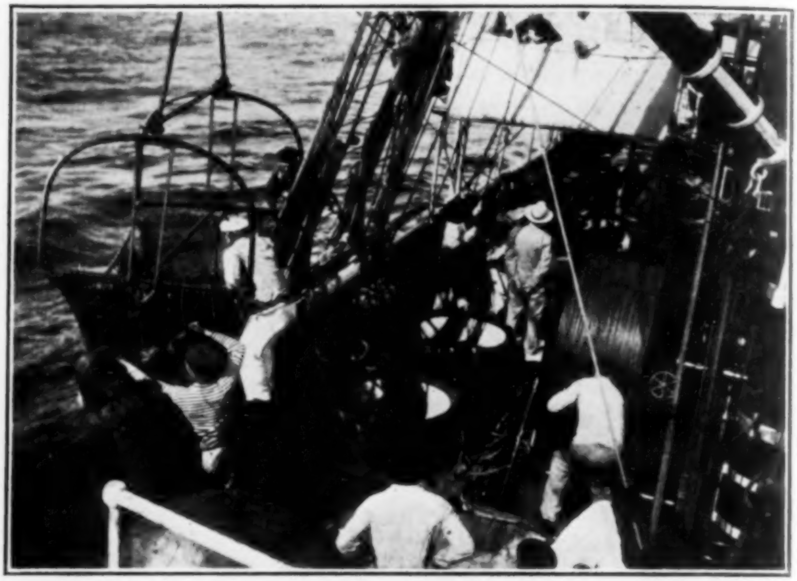
found floating as a corpse in the very early morning before the sea-birds have picked up these remnants of nightly struggles for life. After the improvements in our operations, unexpected facts were gradually brought to light and confirmed by other oceanographers. And in 1912 I obtained, by turning to account the bathometer above mentioned, which had been manufactured in Germany with great difficulty, the true curve of the levels the net had passed through in one operation.

Shortly after, I was able to make a net the opening and closing of which could be controlled on board the ship. This ensemble of improvements enabled us to establish, by means of operations carried out by day and by night at various depths, that there exists in those vast spaces a whole bathypelagic world undergoing vertical oscillation by which some individuals are dragged up from the lowest level at which they live to within fifty meters of the surface, the process occurring only at night. Consequently, we now find at about midnight, quite close to the surface, strange animals which we formerly, when operating in broad daylight, had to seek through most elaborate means at a depth of several thousand meters. Hence we know that those animals live in a state of perpetual vertical oscillation the period of which is twenty-four hours. We have also found that such animals as are able to undergo this enormous displacement more frequently belong to the species provided with luminous organs.

Of the broad researches to which I have applied myself for over a quarter of a century in order to throw light on the problems concerning the science of the sea, I will mention here my investigation of the currents in the North Atlantic Ocean. Those motions of the sea waters, so varied and at times so extensive, which are chiefly brought about by meteorological influences, in their turn exercise a considerable influence over life in the seas. This occurs through the distribution of the plankton, which is an entire fauna of forms extremely minute and therefore unable to direct themselves among the sea-forces.

The plankton—the miniature animal and plant forms of the sea world—is, consequently, swept about by currents over special regions of the sea and is followed by troops of stronger animals that feed upon it and are themselves fed upon by a yet mightier fauna. So it comes about that there has been established in the living sea-world, from the plankton masses to the biggest cetaceans, a broad cycle wherein we see life constantly arising out of death, amid the waters striving for their equilibrium. Currents thus exercise supreme influence over the shoals of sardine or herring, as well as a good many other fish which they supply with food under such conditions, that once upon examining the stomach of one of those fish, we could calculate the number of peridinians lying there at twenty million.

Out of the ensemble of the facts concerning the history of sea-



DREDGING WITH THE NET ON BOARD THE "PRINCESSE ALICE," THE YACHT BUILT BY THE PRINCE OF MONACO FOR THE STUDY OF OCEANIC LIFE. VOYAGE OF 1908

organisms I see more convincing grounds arise for regarding the sea as the cradle of life. Looming on the horizon of human knowledge, I descry the line of the species sprung one from another as they are distributed between surface and bottom. And while I compare that world, which has remained homogeneous through the ages, with those more distinct animals held on one plane on the earth's surface as though they had fled from the ocean, it seems to me that the whole of this terrestrial fauna because of its slower evolution tends to speedier disappearance, owing to the unstable light environment. A few groups, the pinnipedes and cetaceous mammalians, for instance, have not been able to gain even the requisite fitness and have remained half and half, with imperfect means of breathing and locomotion.

Having for a score of years observed the currents of the North Atlantic Ocean by means of extensive experiments based on organized flotation methods, I was, when the German war broke out, quite prepared for the question of what becomes of the wandering mines drifting from the mine fields which were soon placed near the coasts of both continents. I again took up my previous formulae which had enabled me to draw a chart of the great currents sweeping along or connecting Europe and America, and owing to the similarity between the drifting of mines and the method I had used during my earlier investigations it became possible for me recently to present the navigators on the North Atlantic Ocean with a very accurate chart of the course followed by those formidable engines. On this chart one can see an

AIMING AT A WHALE (1902)

immense cycle, whose center is indicated by the Azores, described by the mines in a period of about four years, such being the space of time necessary for the completion of their voyage from the English Channel to the Canaries, the West Indies and back.

My calculations for this work are accurate with respect to the direction and the velocity of the currents, for the hydrographical and meteorological officers on both sides of the ocean observe the passing by or meeting of mines in the manner I had announced to navigators. The two sets of results mutually confirm each other after thirty-five years' interval.

I will content myself with quoting here some phenomena connected with orientation in animals in their relation to the sea.

One of my operations, carried out with a large fish-pot at a depth of about 1500 meters, brought up not only very large *Geryon* crabs, which had been caught inside, but a number of the same clinging to the outside. Thus I witnessed the perplexity the latter must have been in through want of resolution when the fish-pot was just leaving the bottom. They were merely crawlers, unable to swim; and a sudden separation from the bottom whereon the apparatus was lying prevented them from being resolute enough to drop back to their environment by simply falling down the very small height by which at first they were separated from it. They allowed themselves—for they were found to be thoroughly alive—to be lifted through a height of 1500

FIRING A LANCE HARPOON FROM A CANNON AT A WHALE IN THE ARCTIC OCEAN.
Photograph by Lieutenant Bouree

meters up to the surface in spite of the inconvenience they must have felt owing to the change in temperature and the decrease in pressure.

Another time, in the Mediterranean between Corsica and France, I met with a large whale which was apparently repairing to a predetermined goal, and accompanied it with my ship the "Princesse-Alice," keeping close to its flank. For six hours it went on the same compass-route, without departing from it more than two or three degrees, covering about 40 kilometers without a deviation although there was no visible object to guide it. Moreover, its divings and surface breathings, as measured with a chronometer, showed no marked differences, 10 minutes under water alternating with 6 to 8 breathings.

Lastly, with respect to terrestrial birds flying over the sea in their migrations, I have always found facts showing complete lack of orientation under definite circumstances. Thus they swerve from their northward or southward route when there is no more land in either of these directions. The migratory birds swept by some storm away from continental Europe at length drop down to the sea, lacking the instinct which would help them to find the lands that sometimes lie a short distance eastward.

On the other hand those birds which in their chance-guided endeavors have been so lucky as to reach the Azores never afterwards left them. Several of these islands are therefore peopled with wood-

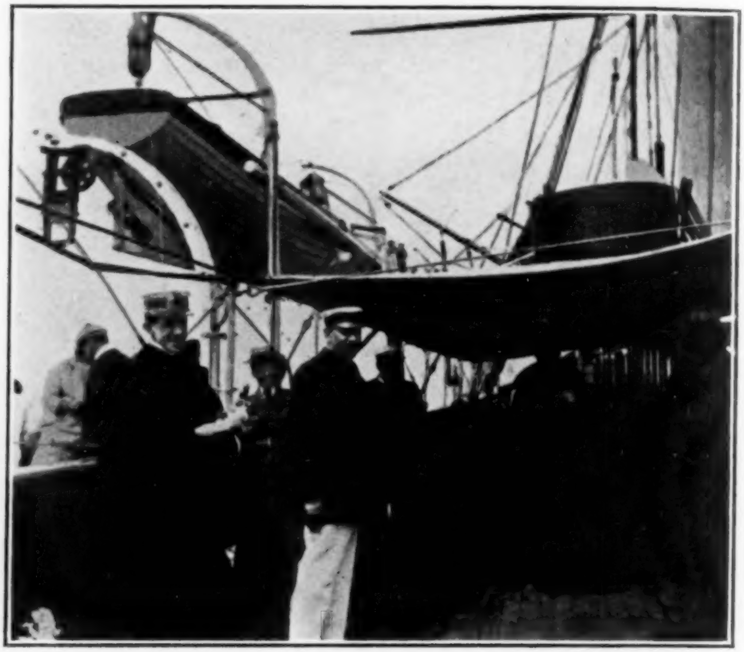
A METEOROLOGICAL KITE FROM THE EXPLORING YACHT IN THE MEDITERRANEAN (1906)

cock and quail and wood-pigeons, which never depart; and there can be visited at São Miguel de Ponta Delgado a large collection of species captured under those circumstances.

With regard to phenomena relating to light, Messrs. Bertel and Grein have pursued very important investigations at the Monaco Oceanographical Museum concerning the penetration of the various light radiations into the depth of sea-water. Mr. Grein in particular has succeeded in securing a photographic print on highly sensitive plates exposed between 10 a. m., and 1 p. m., at a depth of 1500 meters.

The main results may be stated as follows: If we set down as 1000 the amount of light radiations reaching 1 meter down, we find that there remains at 5 meters but 3.7 of red and at 50 meters but 0.0021; at 5 meters there remains but 2.5 of orange-yellow and at 100 meters but 0.001. For green the figures are 230 at 5 meters and 0.0003 at 1000 meters; for blue they are 450 at 5 meters and 0.0001 at 1000 meters; for violet blue, 866 at 5 meters, 0.003 at 1000 meters, and 0.00001 at 1500 meters.

It was already known that the light radiations were absorbed in the above order but in what ratios they reach various depths was not known. M. Grein has moreover stated the ratios of the various percentages of radiations at any given depth: thus at a depth of 1 meter there are 96.7 per 1000 of red; 165.7 of orange yellow, green and



THE KING OF SPAIN (LEFT) AND THE PRINCE OF MONACO (RIGHT) ON BOARD THE PRINCE'S YACHT, THE "PRINCESSE ALICE," AT ST. SEBASTIAN. (JULY, 1903)

green blue; 198.9 of blue; and 207.3 of violet blue. Below 1000 meters only blue remains and below 1500 meters only violet blue.

But there is still one question of biology that offers a very great deal of interest. On my ship Dr. Charles Richet, assisted by Dr. Portier, brought to light the following facts: The tentacles of certain marine animals like *Physalia* provoke by simple contact local irritation and hypesthesia. When injected with the extracts from these tentacles the dog, the pigeon, and other animals are plunged into a state of conscious semi-narcosis more or less prolonged during which they remain absolutely insensible to pain. Richet and Portier have named this benumbing substance "hypnotoxine."

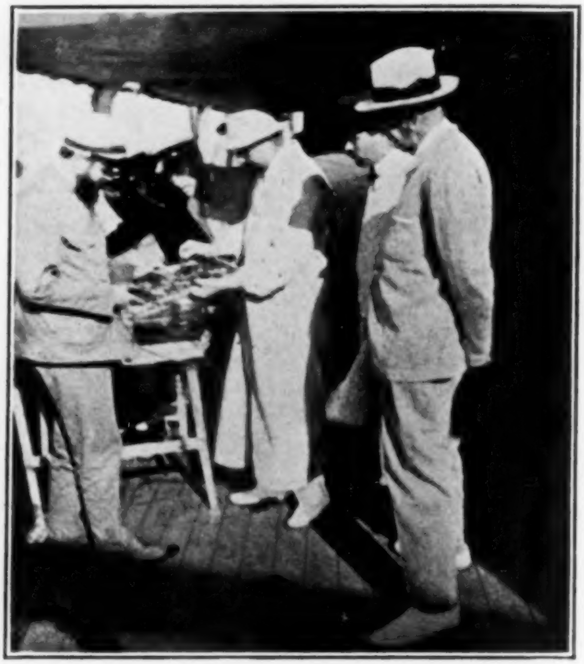
In experimenting with extracts from the tentacles of certain sea-anemones, Richet and Portier found that dogs after having received one injection became *excessively susceptible* to the action of a second dose. These dogs could be killed by a quantity representing only a fraction of the dose that would be fatal for a dog not previously treated. They gave the name "anaphylaxis" to this state of abnormal sensitiveness of a subject to the action of certain substances, which might be foreign albumens of any kind, animal or vegetable; for example, the blood-serum of an animal *of a different species*, egg-albumen, substances usually harmless like milk, the extracts of various organs, bacteria or the extracts from bacteria (bacterial proteins) etc.

THE PRINCE OF MONACO (RIGHT) AND MR. KOHN (LEFT) ON BOARD THE "PRINCESSE ALICE" ON THE VOYAGE OF 1905. Photograph by Dr. Richard, Director of the Monaco Museum

If, for example, a small amount of serum from the horse, even one one-hundredth of a cubic centimeter, is injected into a guinea-pig, the latter is rendered hypersensitive to horse serum. This hypersensitiveness goes *completely unnoticed* unless after a certain lapse of time the guinea-pig is again injected with serum from the horse; under these conditions the anaphylactic state reveals itself by a condition of "shock" with grave symptoms and sometimes even death in a few minutes.

There was at first considerable surprise and incredulity because scientists had hitherto been accustomed to regard the reaction of immunization or of diminution of sensitiveness as the appropriate response of an organism to the injection of foreign substances. It was therefore astonishing that exactly the opposite phenomenon could result. Thus the laws of immunity were completely upset.

Though but a few years have passed since the condition of anaphylaxis was studied for the first time, it has now become one of the subjects which have brought forth the most work in the domain of immunity. The amount of research carried out upon anaphylaxis is enormous, and every day its literature increases. It is a field of the highest importance not alone on account of its practical application in serum therapy but because as a mystery it enfolds within its depths the secret of many deep-seated questions relating to mankind; also



EXAMINING A CATCH OF THE BOUREE NET

because the researches already performed upon anaphylaxis give great hopes for the elucidation of these questions and for the discovery of a method of rendering the human body insusceptible.

Among the things which contribute to the harmony of our terrestrial sphere we should observe the rôle played by the marine plants as frequently intermediaries between the living and the lifeless realms of our planet. While on the one hand they furnish for many organisms both protection and nourishment, still another important function falls to their lot: they fix certain mineral substances which are more or less abundant in the bosom of the ocean and deliver them up for exploitation by human activity. Thus it would be eminently fitting to conserve and to cultivate these products of the sea which are to-day our auxiliaries in obtaining iodine, bromine, algine, chloride of sodium, and the salts of potassium, magnesium, lime, iron and manganese. Unfortunately in some places they are already the victims of waste. Finding himself in the presence of wealth, one might say, man loses completely the idea of providence. He seems then to suffer from a vertigo which drags him to the radical destruction of things for there is no gift of nature that can survive the ill-considered enterprises of human industry.

Paul Gloess has said: "It is in the marine plants that we find, and shall always find with more certainty than elsewhere, that which thus far in our carelessness we have neglected to ask of them or which

A FISHING SCENE ON BOARD THE "HIRONDELLE," THE YACHT BUILT BY THE PRINCE OF MONACO FOR OCEANIC EXPLORATION. FROM LEFT TO RIGHT ARE PRINCE ALBERT I OF MONACO; L. TINAYRE, ARTIST; DR. RICHARD, DIRECTOR OF THE MONACO MUSEUM; M. FUHRMEISTER, PRIVATE SECRETARY, AND DR. LOUET, PHYSICIAN

in our extravagance we have squandered. * * * The fertile soil of the earth is constantly becoming poorer while the nourishing fluid of the sea is growing richer and richer."

All these data are valuable for the study of the beings living at various depth-levels in the ocean.

A professor at my Oceanographical Institute, Monsieur Joubin, has lately suggested the use of seaplanes to help open-sea fishermen by guiding them towards the shoals of the fish they are seeking while the latter in their turn are pursuing large shoals of such crustacea as serve them for food. For instance, it has been found that the germon (the blue tunny in the Bay of Biscay) is plentiful in the places tenanted by certain red-colored amphipodous crustacea (*Euthemisto*) of which the germon is fond. Seaplanes would have no difficulty in signalling to fishermen those red fields which distinctly mark off certain spaces in the sea and move about as they are swept by the currents. Again, they could signal the presence of various other shoals recognizable by different signs. Thanks to this cooperation, fishermen might save time and much undue wear of their nets.

Now I shall take up a matter which I have had in hand for some time and which is one of a really serious nature. I mean fishing generally, the destructive effects of which are becoming greater and greater in the seas where more and more powerful and numerous implements such as steam trawlers are being used. The latter now graze

the very soil of continental plateaux, plucking off the sea-weeds and ruining the bottoms that are fittest for the breeding as well as the preservation of a great many species. So much so that in a few years' time the means of maintenance of hundreds of thousands of fishermen and their families on the coasts of Europe will have disappeared.

The trawlers steadily work farther and farther, deeper and deeper, in ever increasing numbers; and wherever their devastation is possible a waste is involved which certainly exceeds 50 per cent. of the edible produce they seek. For we must include in this summary valuation the young the trawl maims and kills as it passes and those that reach the ship in such condition that they are useless and in some cases untransportable. Near the Arguin bank on the west African coast a still more intensive waste occurs which is owing to purely commercial causes.

In order to check this evil, I suggest the meeting of international conferences possessing the most drastic powers to enforce the decisions that are to be arrived at. I would recommend the adoption of the reserved district principle, which has always been very efficient for the preservation of wild terrestrial species, because it rests on logic and simplicity. Besides, it is now showing its value in those parts of the sea where the war raged and fishing was held up for a few years; as soon as fishing was resumed plenty of fish has been found, some specimens being of a size unheard of for thirty years.

I have included within the domain of oceanography, for the present at least, the study of phenomena observed in the upper atmosphere floating over the oceans. That these expanses receive from the sea the principal elements of their activity seems evident when one remembers the effects of evaporation on an immense scale and of the winds which sweep continually over the surface of the waters.

Only with a great deal of difficulty have we succeded in obtaining observations on the speed and direction of the wind and the temperature and humidity of the air up to altitudes of 25,000 meters. During several years I pursued, by means of aluminum instruments weighing very little, the delicate experiments which these researches entail. In the construction of these instruments Professor Hergesell, who now accompanied me, had participated. Just as the Americans, Edy and Rotch, had already done, I at first entrusted my instruments to kites which carried them up to 4500 meters. But soon I abandoned this means and adopted a new one which, on land, furnished satisfactory results to the French investigators Hermite and Bezancon. This was an arrangement of two linked balloons unequally filled, of which the one less inflated carried the instruments. On reaching a certain height the better filled balloon would be burst by the expansion of the gas it contained, whereas the second, not sufficient alone to carry the weight of the instruments, redescended toward the surface of the sea. I was able to make such apparatus reach an altitude of 14,000 meters.

THE PRINCE OF MONACO VISITING THE GROTTO DEL CASTILLO, SPAIN, WHICH HE EXPLORED FOR PREHISTORIC HUMAN REMAINS. THE PRINCE IS SEATED ON THE RIGHT OF THE CAVE'S MOUTH, WHILE ON THE EXTREME LEFT STANDS HIS COLLABORATOR, THE ABBE BREUIL, AND NEXT TO HIM THE ARTIST OF THE EXPEDITION, LOUIS TINAYRE

The most serious difficulty presented in these operations was always that of recovering the balloon that carried the instruments after its descent to the sea, since the point of its fall was sometimes 50 to 100 miles distant from that of its ascent and in a direction quite different from what the wind at lower levels would indicate. Moreover, the whole apparatus, though followed by the ship and located repeatedly as long as it remained visible, would finally disappear without our being able subsequently to judge the effect of the wind which carried it.

On board the "Princesse-Alice II" we solved this problem by special calculations which allowed us to mark on a map, as soon as the balloon had disappeared from view, an approximate point toward which to direct the course in order to rediscover it without fail. Thanks to an ingenious idea of Professor Hergesell, this balloon left to itself remains floating with its instruments at a height of 50 meters above the water, its lifting power being recovered through a weight suspended below which has only to touch the surface.

By using much smaller balloons, of about 1-meter size, which carried no instruments but the movements of which were measured with the theodolite as long as it was possible to observe them, we succeeded, in arctic regions, in determining the velocity and direction of the wind in the upper layers of the atmosphere, even up to 25,000 meters, as before mentioned. Then our balloon was 80 kilometers from us in a straight line; that such a visibility is possible results from the limpid

THE PRINCE OF MONACO AND HIS PARTY VISIT THE GROTTO OF LA PASIEGO, NEAR PUENTE VIESGO, NOT FAR FROM SANTANDER

arctic atmosphere free from dust and water-vapor. This same limpidity permitted me one day to follow easily all the actions of 4 men whom I had sent on a mission to a snowfield situated at a distance of 40 kilometers towards the interior of Spitzbergen.

To-day, therefore, I can release in the open ocean a balloon of 2- or 3-meter size furnished with instruments and can find it mathematically after it has made a long journey in a direction of which we otherwise would have to remain totally ignorant.

I shall close my all too brief survey of the mighty domain created by the science of oceanography by speaking to this distinguished assembly of the bathymetric chart of all the seas of the globe the preparation of which I undertook at the time of the International Congress at Berlin in 1899. I realized then that this task was necessary as a basis and a program for the great work to which I have consecrated my life. To Commandant Bourée I entrusted the direction of this enterprise and to-day its imperativeness is already evident. All the hydrographic and oceanographic centers of the world have appreciated this fact and are now sending me abundant data bearing on the subject.

This chart, on a scale 1 to 1,000,000, occupies 24 sheets and measures, without its separate polar circles, 2 meters 40 cm. by 4 meters. The isobathic lines are those of 200, 500, 1000, 2000 meters, and so on.

The surfaces contained between succeeding contours are colored in blues becoming progressively deeper in shade. The oceanic regions of which the depth still remains unknown are immediately disclosed.

If we had no more rapid system for taking soundings than that which requires each time the stopping of the ship to send a lead to the bottom, many years would still be required for the completion of such a task; but the method of M. Marti, a hydrographic engineer in the French navy, will doubtless soon enable us to take lines of soundings with almost the usual speed of a ship under way.

M. Marti obtains the marking upon a very sensitive recorder of a slight explosion produced always under the same conditions. This record being repeated in like manner by the echo sent back from the submarine floor allows of a measurement of depth with greater precision than by any other procedure. The principal experiments have been carried on at the Oceanographic Museum of Monaco and it is to be hoped that M. Marti's method of sounding will be employed everywhere. When applied to slight depths it would render great services to navigation; and as for my bathymetric map, it would very soon be completed.

I have already told you that my life has been occupied in anthropological research as well as in oceanographic studies. My conjectures on the origin of life in the sea carried with them as a necessary corollary the formation of a group of beings susceptible to the laws of evolution in such a way as to be led toward the synthetic whole that has become the human form. Hence it was necessary to seek in the series of marine animals, either among the living or among the fossils which led the same life, whatever indications might shed light upon such a question. From what marine ancestors has come the stem of anthropoids from which one may ask the secret of the drama in which we are now taking part?

In the midst of these reveries came the desire to found, under the conditions of independence necessary for the development of scientific truth, a home where anthropology could grow freely in the solicitude accorded by the most trusted disciples of this science. So I created beside the Oceanographic Institute of Paris the Institute of Human Paleontology, where the professors without gathering cumbersome collections study all the materials with which excavations supply us.

I come among you the better to express my happiness and my pride in the great favor you have done me by bestowing upon me this medal which commemorates the work of oceanographers. Nothing could honor more the efforts to which I have consecrated my life that the spirit of men might no longer be left ignorant of all that concerns the science of the sea when it had already penetrated so many secrets of the earth, this infinitesimal portion of the universe.

THE PROGRESS OF SCIENCE

THE SECOND INTERNATIONAL CONGRESS OF EUGENICS

Arrangements are well advanced for the International Congress of Eugenics which will be held at the American Museum of Natural History, beginning September 22. The officers are: Honorary president, Alexander Graham Bell, Washington, D. C.; president, Henry Fairfield Osborn, Columbia University and the American Museum; honorary secretary, Mrs. C. Neville Rolfe, London; treasurer, Madison Grant, chairman of the Zoological Society, New York; secretary-general, C. C. Little, Department of Genetics, Carnegie Institution of Washington.

The congress is organized in four sections. In the first section will be presented, on the one hand, the results of research in the domain of pure genetics in animals and plants, on the other, studies in human heredity. The application to man of the laws of heredity and the physiology of reproduction as worked out on some of the lower animals will be presented. The leading address will be by Dr. Lucien Cuénot, Nancy, France.

The second section will consider factors which influence the human family and their control; the relation of fecundity of different strains and families and the question of social and legal control of such fecundity; also the differential mortality of the eugenically superior and inferior stocks and the influence upon such mortality of special factors, such as war and epidemics and endemic diseases. First in importance among the agencies for the improvement of the race is the marriage relation, with its antecendent mate selection. Such selection should be influenced by natural sentiment and by a knowledge of the significant family traits of the proposed consorts and of the method of inheritance of these traits. In this connection will be brought forward facts of improved and unimproved families and of the persistence, generation after generation, of the best as well as of the worst characteristics. The leading address will be by Dr. Herman Lundborg, Upsala, Sweden.

The third section will concern itself with the topic of human racial differences, with the sharp distinction between racial characteristics and the unnatural associations often created by political and national boundaries. In this connection will be considered the facts of the migration of races, the influence of racial characteristics on human history, the teachings of the past with bearings on the policies of the future. The results of research upon racial mixture in relation to human history will be presented. Also the topics of racial differences in diseases and psychology will be taken up. The history of race migrations and their influence on the fate of nations, especially modern immigrations, should be set forth. The leading address will be by Dr. M. V. de Lapouge, Poitiers, France.

The fourth section will discuss eugenics in relation to the state, to society and to education. It will include studies on certain practical applications of eugenic research and on the value of such findings to morals, to education, to history, and to the various social problems and movements of the day. In this section will be considered the bearing of genetical discoveries upon the question of human differences and upon the desirability of adjusting the educational program of such differences. Here will be considered the importance of

family history studies for the better understanding and treatment of various types of hospital cases and those requiring custodial care. The bearings of genetics on sociology, economics and the fate of nations may be considered in this section. The leading address will be by Major Leonard Darwin, London.

In connection with this congress a Eugenics Exhibition will be held from September 22 to October 22, in the Forestry Hall of the American Museum of Natural History. It is desired to secure the most striking exhibits available or which can be prepared for this purpose. While the exhibits must be able to withstand the test of professional scrutiny, still they should be of a nature which the man of ordinary intelligence and education, but without special scientific training, may readily comprehend and appreciate. Provision will be made for exhibiting displays of highly technical work, but the popular aspect will be given the preference.

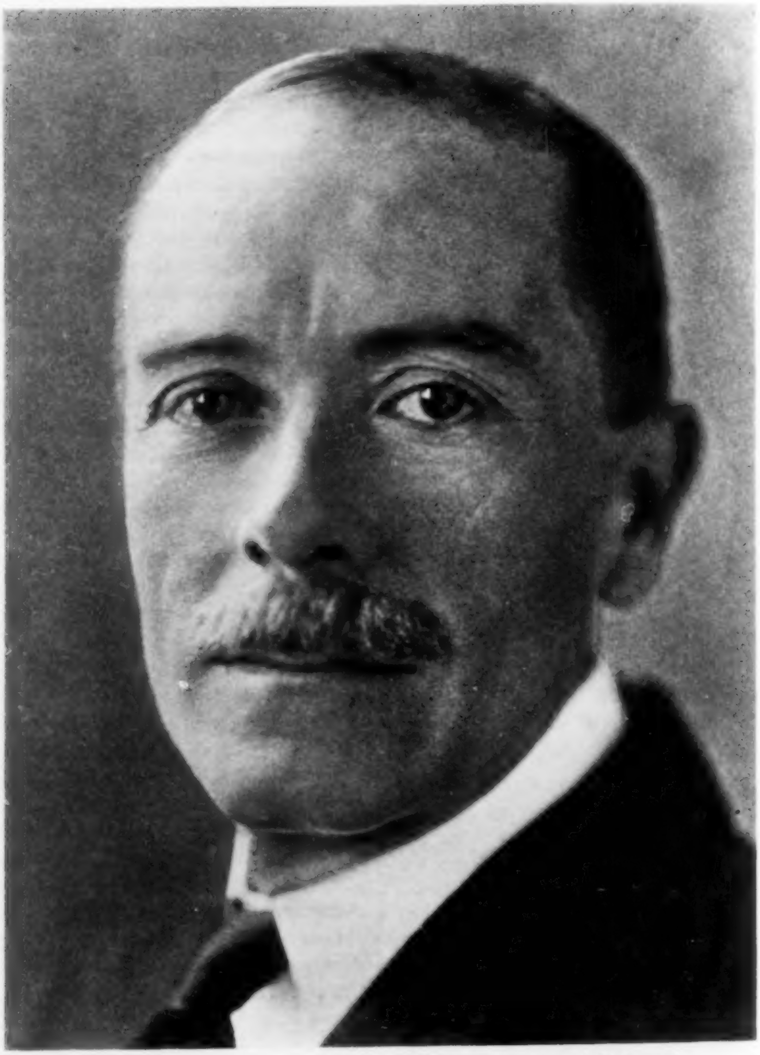
THE EDINBURGH MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The British Association holds its eighty-ninth annual meeting at Edinburgh, from September 7 to 14. According to an announcement in the London *Times*, the president, Sir Edward Thorpe, will address the association on aspects and problems of post-war science, pure and applied. An evening discourse will be given by Professor C. E. Inglis on a comparison of the Forth and Quebec Bridges, and there will be an opportunity to visit the former. Another discourse will be given on Edinburgh and oceanography by Professor W. A. Herdman, who, it will be remembered, as president of the association at Cardiff last year, pressed for a new exploration of the oceans like that of the *Challenger*, nearly 50 years ago.

Some presidents of sections will introduce discussions on their addresses. Hitherto all addresses have been formally read, and never discussed, but in the present program the following addresses are announced to initiate debates: Sir W. Morley Fletcher, on the boundaries of physiology; Professor Lloyd Morgan, on consciousness and the unconscious, opening the newly established section of psychology; Dr. D. H. Scott, on the present position of the theory of descent in relation to the early history of plants; Sir Henry Hadow, on the place of music in a liberal education; and Mr. C. S. Orwin, on the study of agricultural economics. Other addresses will be given on problems of physics by Professor O. W. Richardson, on the laboratory of the living organism by Dr. M. O. Forster, by Dr. J. S. Flett on experimental geology, by Professor E. S. Goodrich on some problems in evolution, by Dr. D. G. Hogarth on the application of geography, by Mr. W. L. Hichens on principles by which wages are determined, and by Professor A. H. Gibson on water power.

This year the council called all sectional committees to meet together to consider common action, and out of many suggestions then received several topics of first-rate importance were selected to be debated by appropriate groups of sections, at joint meetings which will form the principal items of the sectional programs. These topics include the structure of molecules, the age of the earth, biochemistry, the proposed Mid-Scotland canal, the origin of the Scottish people, vocational training and tests and the relation of genetics to agriculture.

Among the other promised features there is a popular exposition of Einstein's theory of relativity by Professor A. S. Eddington; and the usual public lectures will be given to the



Photographed by Underwood and Underwood.

DR. LIVINGSTON FARRAND

Elected president of Cornell University to succeed Dr. Jacob Gould Schurman. President Farrand has been adjunct professor of psychology and professor of anthropology in Columbia University, president of the University of Colorado and chairman of the Central Committee of the American Red Cross.

citizens of Edinburgh. The speakers will include Sir Oliver Lodge on speech through the ether, Professor A. Dendy on the stream of life, and Professor H. J. Fleure on countries as personalities, and a special lecture will be arranged on market day in Edinburgh for the agricultural community by Dr. E. J. Russell on science and crop production.

The association, having failed to regain its former concession of reduced railway fares for members, proposes that they shall be offered facilities for traveling by motor coach to Edinburgh from most of the university and many other principal towns in England, at fares substantially less than those of the railways. Full particulars of membership may be had from the office of the association at Burlington House, or from the local secretary at the University of Edinburgh.

MEETINGS OF BRITISH AND AMERICAN CHEMISTS

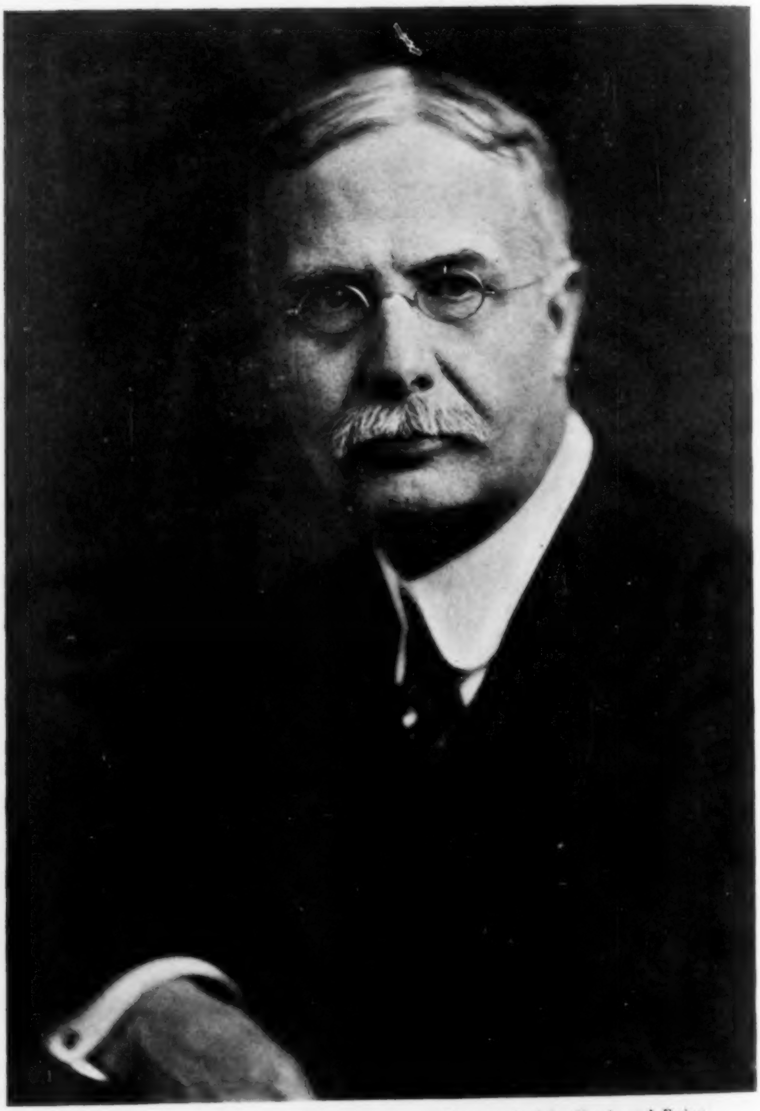
Joint meetings will be held this autumn by chemists of Great Britain, Canada and the United States. Members of the Society of Chemical Industry of Great Britain will join with the Canadian branch of their organization in sessions in Montreal late in August. The scientific and business sessions will center at McGill University, where there will be a special convocation. The Canadian and British chemists will inspect numerous plants and will proceed to Ottawa and Toronto, where they will be entertained by the local sections. On September 5, they will reach Niagara Falls, where they will view the vast establishments which modern physics and chemistry have created.

The members will then cross the border, being met by a committee of the American section of their society and conducted through the industrial plants on this side of the Falls. Dinner will be served at Buffalo, and on their arrival at Syracuse, they will have luncheon with the Solvay Process Company. The chemists will then go to Albany and New York City, where they will be welcomed by the American Section of the Society of Chemical Industry. Elaborate arrangements for the reception of the chemists will be carried out, through the co-ordinating committee, of which Dr. B. C. Hesse is chairman and Dr. Allen Rogers is secretary. The festivities, meetings and entertainments which will follow are designed to bring into closer bonds all chemists of Anglo-Saxon stock.

The fall meeting of the American Chemical Society, with its 15,500 members, is to be held in New York City from September 6 to 10, inclusive. The first contact will be at a lawn party, to be given on the afternoon of September 7 to foreign guests and to scientific societies at Columbia University. Other societies asked to participate in the welcoming of the visitors from abroad are: The American Electrochemical Society; the American Institute of Chemical Engineers; the American Section of the Société de Chimie Industrielle; and the Manufacturing Chemists' Association of the United States. The foreign guests have also been invited to the smoker and entertainment of the American Chemical Society, which will be held on the evening of Wednesday, September 7.

Scientific sessions of the American Chemical Society, in which many matters concerning chemical research and applied chemistry will be discussed, are to be held at Columbia University. To these meetings the British and Canadian guests have been bidden. They will also be present at the banquet of the American Chemical Society on the evening of September 9 at the Waldorf-Astoria.

The fortnight beginning September 12 will be dedicated to American



Photographed by Harris and Ewing.

EDWARD BENNETT ROSA

chemistry in all its phases, for it marks the holding of the National Exposition of Chemical Industries, which is to be held in the Coast Artillery Armory in the Bronx. There will be brought together under one roof a demonstration of what has been accomplished in this country since the European War in adapting the resources of the United States to national needs.

EDWARD BENNETT ROSA

The death of Dr. Edward Bennett Rosa, chief physicist of the Bureau of Standards, Washington, D. C., is a serious loss to science and to the government service. Born in Rogersville, N. Y., in 1861, he was a graduate of Wesleyan University in the class of 1886, receiving the degree of doctor of philosophy from the Johns Hopkins University in 1891. For a short time he was instructor at the University of Wisconsin, leaving there to become professor of physics at Wesleyan University. He became the chief physicist at the Bureau of Standards in 1901.

He did notable work in science and electrical engineering. At Wesleyan University he developed the physical side of the respiration calorimeter with Professor W. O. Atwater. This apparatus was of great value in the pioneer investigations on the value of foods and the study of nutrition problems. He took a leading part in the researches to establish the fundamental electrical units after going to the Bureau of Standards and served as secretary of the International Committee on Electrical Units and Standards. He has developed the electrical work of the Bureau of Standards from small beginnings into an organization covering the scientific and engineering aspects of a great national laboratory.

When Dr. Rosa began his work in the Electrical Division it was his ambition to determine a number of the fundamental electrical constants. In conjunction with Dr. Dorsey he immediately undertook the determination of the ratio of the electromagnetic and electrostatic units. About 1907 they started their work on the determination of the ampère. This was followed by work on the silver voltameter and apparatus for determining the absolute value of the ohm.

During his early years at the bureau, Dr. Rosa published a large number of papers on the computing of inductance, and later, with Dr. Grover, he collected together practically all the known formulae for computing inductance. In 1910, there was instituted under Dr. Rosa's direction an exhaustive investigation into the subject of electrolytic corrosion of underground gas and water pipes, and lead cable sheaths due to stray currents from electric railways.

During the war, Dr. Rosa directed the development of a number of scientific instruments which were of inestimable value to the American Forces in France. Among these might be mentioned a sound-ranging device for locating big guns; the geophone for the detection of mining operations, the development of aircraft radio-apparatus, and the improvement of radio.

In addition to his diversified work in the field of electrical research, Dr. Rosa was keenly interested in the prevention of industrial accidents and in the promulgation of safety standards for use by state, municipal and insurance organizations. He conceived the idea of a National Electrical Safety Code several years ago, and the present code is largely the result of his efforts. Similarly the bureau has undertaken a number of other national safety codes, the Safety Code Section working under his direction.

His broad vision showed him the need of a central clearing house for

engineering standards. For years he worked whole-heartedly to bring about the formation of such an organization. It was due in no small measure to his efforts that the American Engineering Standards Committee is now functioning.

The broader aspects of the scientific and engineering work of the Federal Government were clearly presented in a series of papers by Dr. Rosa. His analysis of government expenditures, printed in this journal, was largely quoted by leading periodicals as well as in both Houses of Congress.

SCIENTIFIC ITEMS

We record with regret the death of Dr. Francis Bacon Crocker, the electrical engineer, formerly professor at Columbia University; of Dr. Marshman Edward Wadsworth, dean emeritus of the School of Mines of the University of Pittsburgh, and of Dr. Gabriel Lippman, professor of physics in the University of Paris.

Dr. Frank Pierrepont Graves, dean of the school of education of the University of Pennsylvania, has been appointed commissioner of education of the state of New York and president of the University of the State of New York.

The Adamson lecture was delivered at the University of Manchester on June 9 by Professor Einstein, who had been invited by the council in accordance with a senate recommendation passed on February 3. At the opening of the proceedings the honorary degree of D.Sc. was conferred on him. Professor Einstein lectured on June 13 at King's College, London, on "The development and present position of the theory of relativity." After the public lecture Professor Einstein was the guest of the principal of King's College at a dinner given in the college.

The Louisiana State University will receive $7,500,000 for new buildings and equipment as a result of the action of the Constitutional Convention which has just adjourned, this sum having been set apart for the purpose from funds accruing from the newly established severance tax on oil and other natural resources. Plans are now being made for the erection of the new buildings on a tract of two thousand acres near Baton Rouge, Olmstead Brothers, of Brookline, Mass., having been secured as landscape architects. The new constitution, which has just gone into effect, also provides for a half-mill tax, which it is estimated will yield an annual income of approximately a million dollars for the maintenance of the university.